RESOURCE MOBILIZATION, WATER ALLOCATION, AND FARMER ORGANIZATION IN HILL IRRIGATION SYSTEMS IN NEPAL

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

Edward D. Martin

January 1986

Resource Mobilization, Water Allocation, and Farmer Organization in Hill Irrigation Systems in Nepal

Edward D. Martin, Ph.D.
Cornell University 1986

In the hill region of Nepal, irrigation has been a primary input in agricultural production for decades in some villages and for centuries in others. Most of the irrigation systems in the hills are owned and managed by the farmers themselves. In the face of a rapidly growing population and increasing demand for food production, farmers have been intensifying both agricultural production and the management of irrigation systems. The focus of this research has been on farmer-managed irrigation systems and the ways in which the farmer organizations perform irrigation management activities, particularly water acquisition, allocation, and distribution, as well as resource mobilization. Over twenty-five systems were observed, and eight organizations in four locations were studied in detail during the 1982-83 crop year.

Irrigation systems on river terraces with varying levels of available water supply relative to the irrigable land were selected for study to analyze (1) the relationship of management intensity to relative water supply, and (2) the impact of water supply on the structure of irrigation organizations and on efficiency and equity in water use.

The irrigation organizations were found to practice more intensive management of distribution of water, the lower the water supply relative to the area irrigated. However, the factor found to be most determinative of the structure of the organizations was the amount of resources needed to be mobilized to maintain the irrigation system.

Allocation of water rights and careful distribution of the water supply in accordance with each member's entitlement were found to be closely related to the level of resources needed to be mobilized for maintenance of the system. Where the costs of maintaining the system were high, the allocation of water rights was explicitly defined, and methods for strict and accurate distribution of the water in conformance with the pattern of allocation were well developed.

A linear programming model was developed to determine the trade off between the supply of water and level of management input needed to achieve a given level of crop production. The model was also used to determine the impact on economic efficiency of a shift to water rights based on ownership and sale of water shares. Allocation of irrigation water through sale of shares in the system was found to facilitate the expansion of the area irrigated by a supply.

This study illustrates that the farmer-managed hill irrigation systems of Nepal vary across locations and are changing over time in response to varying resource limitations and growing population pressure. Management inputs have been intensified to achieve greater efficiency in the use of water resources. An understanding of the dynamics of this process should assist external agencies in facilitating the process of transition to a more intensive agricultural production.

BIOGRAPHICAL SKETCH

Edward Douglas Martin was born 2 January 1948 in Sellersville, Pennsylvania. His family soon moved to Harrisonburg, Virginia, and then on to La Junta, Colorado, when he was nine years old. In 1965, he enrolled as an engineering student in Stanford University and graduated in 1970 with a B.S. in General Engineering.

After graduation, he joined the Mennonite Central Committe for three years as a volunteer in Nepal. He taught and supervised apprentices in the electrical department of the Butwal Technical Institute, a training-cum-production facility.

After marrying Kathy Yoder in 1973 and traveling extensively in South and Southeast Asia, he enrolled for one year in the Associated Mennonite Biblical Seminaries in Elkhart, Indiana. In 1975 and 1976, he again worked for the Mennonite Central Committee in Nepal as business manager of a consulting organization engaged in the development of rural energy resources.

Mr. Martin entered a Master of Public Administration program at Cornell University in 1977. After completion of the MPA degree in 1979, he enrolled for the Ph.D. in Agricultural Economics. He conducted dissertation research in Nepal between 1981 and 1983.

Kathy and he have two daughters, Shaunti and Jessica.

ACKNOWLEDGEMENTS

The task of writing acknowledgements is both pleasant and difficult. One is happy to mention the people who have contributed to the completion of the dissertation, but also sadly certain that some names will be unconsciously omitted.

Professors Randy Barker, Milt Barnett, Walt Coward, and Gil Levine first kindled my interest in irrigation management in their course on the Socio-Technical Aspects of Irrigation. Randy Barker as chairman of my special committee continually urged me to bring more focus to the research while helping me to understand broader implications of the findings. His efforts to bring more clarity to sometimes muddled thinking and obtuse writing were much appreciated. Norm Uphoff and Dan Sisler, the other two members of the committee, provided enthusiastic support and stimulating input throughout the project. Dan Sisler's continued encouragement during some of the more difficult days of writing, while the others were on assignments overseas, was essential for the completion of the dissertation. I would also like to thank Tammo Steenhuis and Mike Walter for their interest and warm support.

Without the assistance of a number of people in Nepal, this research would not have been possible. I am particularly grateful to Dr. Prachanda Pradhan for his interest in the study and the insights that he contributed during many discussions. I was fortunate in having a hard-working, faithful set of field assistants and gratefully acknowledge the contributions of Ujjwal, Durga K.C., Duman, Devi, Reshmi, Netra, Shobakhar, Surendra, Ram Nath, Durga Shrestha, and Bodhraj. The people of Argali, Chherlung, Majuwa, and

Thambesi were cooperative, patient, and friendly, and I will long treasure the opportunity that I had to live among and learn much from them.

I appreciate the assistance that Mr. S. B. Gurung, Chief of the Research Division, and Dr. K. L. Shrestha, Director of the Research Centre for Applied Science and Technology, Tribhuvan University gave during the time that I was affiliated with the university. They were most helpful in expediting all administrative matters and were very supportive of the research. I am very grateful to the United Mission to Nepal for allowing the use of their mail and communication facilities and for other assistance. Without the financial support of the Program in International Agriculture and Rural Development at Cornell, Appropriate Technology International, the Ford Foundation, and the USAID Water Management Synthesis Project, this research would not have been possible.

A special note of appreciation for Veit and Brigitte Burger is a must. There home was always open when I arrived in Kathmandu from the field, and I many times enjoyed their warm hospitality.

At Cornell, fellow graduate students Vishva Bindlish, C. M. Wijayaratna, Terrence Abesekera, Ujjwal Pradhan, John Duewel, Ruth Meinzen-Dick, Doug Vermillion, Chris Wensley, Ernie Thiessen, and others provided many pleasant hours of stimulating discussion.

This study was truly a joint effort, and Bob Yoder, my co-researcher, deserves more than half the credit for the results. Without the constant interaction both in Nepal and at Cornell, this study could not have been done. His broad interests and experience were invaluable in the field, and as a personal friend, he was always supportive and encouraging. His wife, Jo, and children, Ryan and Jyoti, were constants sources of fellowhip and support for my family and me.

I cannot thank my wife, Kathy, enough for her constant love, encouragement, and patience during the busy and, sometimes, trying times of completing a Ph.D. She willingly took on more than her share of the work of managing the household and taking care of our daughters. I gratefully acknowledge her contribution in the past month in reading the dissertation and making numerous suggestions which have improved it considerably. Shaunti and Jessica have patiently suffered the busyness of their father, and have provided much joy and happiness.

CONTENTS

TABLES

FIGURES

CHAPTER 1: INTRODUCTION

The research reported here is based on twenty-one months of field study of farmer-managed irrigation systems in the mid-hills of western Nepal.[1] Small-scale irrigation systems operated and maintained by groups of farmers are found in the river valleys throughout the hill region of Nepal. Small canals carry water along precipitous slopes to irrigate terraced fields carved out of the steep hillsides or the more gently sloping expanses of river terraces. Many different micro-environments exist in this region, and these irrigation systems represent one of the essential means for intensifying agricultural production under constraining physical resource conditions.

1.1 Statement of the Problem

Among the many development problems facing the small Himalayan kingdom of Nepal is the critical one of feeding a growing population with the production from a limited land resource. The annual population growth rate, approximately 2.7 percent, exceeds the barely marginal increase in food production (less than 1.5 percent per year in the 1970s), and in 1979-80, for the first time, Nepal experienced a deficit in its trade of food and live animals (Asian Development Bank, 1982). Nepal lies between the two giant Asian countries of India and China and occupies an area of over 141,000 square kilometers, not more than 22 percent of which is cultivable. Nepal is

[1]The irrigation systems studied are owned and managed collectively by groups of farmers. Irrigation systems of this type are often referred to as "communals" or "community-managed" systems (Coward, 1980). The term "farmer-managed" has been used so as to avoid the ambiguities inherent in the term "community."

situated between 26 and 30 degrees north latitude which, in terms of temperature and solar radiation, could be suitable for intensive cultivation. However, the extremely high elevation of much of the land, influenced by the Himalayan range in the northern part of the country, results in a climate over much of the area in which agricultural production is not feasible.

Nepal consists of three distinct topographical regions, distinguished primarily by elevation, which span the country from east to west. The mountains, soaring to an elevation of nearly nine thousand meters, occupy the northernmost region of the country. The tarai is a strip of flat land along the southern border of the country, 10 to 50 kilometers wide at an elevation of 60 to 300 meters; it is actually the northern edge of the Indian Gangetic plain. Between the mountains and the tarai is the region referred to as the "hills." This region consists of deep valleys and hills that were once heavily forested, but which are now largely terraced for cultivation. The elevation ranges from 300 to over 3000 meters, resulting in many different microclimatic conditions. Figure 1.1 shows the three regions and their relative elevations.

Definitive data on physical land use and cultivated area do not yet exist for Nepal (Asian Development Bank, 1982). Table 1.1 presents two estimates of comprehensive studies of the agricultural and irrigation sectors, one by the Water and Energy Commission (WEC) and the other by the Asian Development Bank (ADB).

The main difference between the data used in these two studies is the amount of cultivated land in the hills and mountains. The WEC study used a figure of 650,000 hectares in the hills and 32,000 in the mountains. This

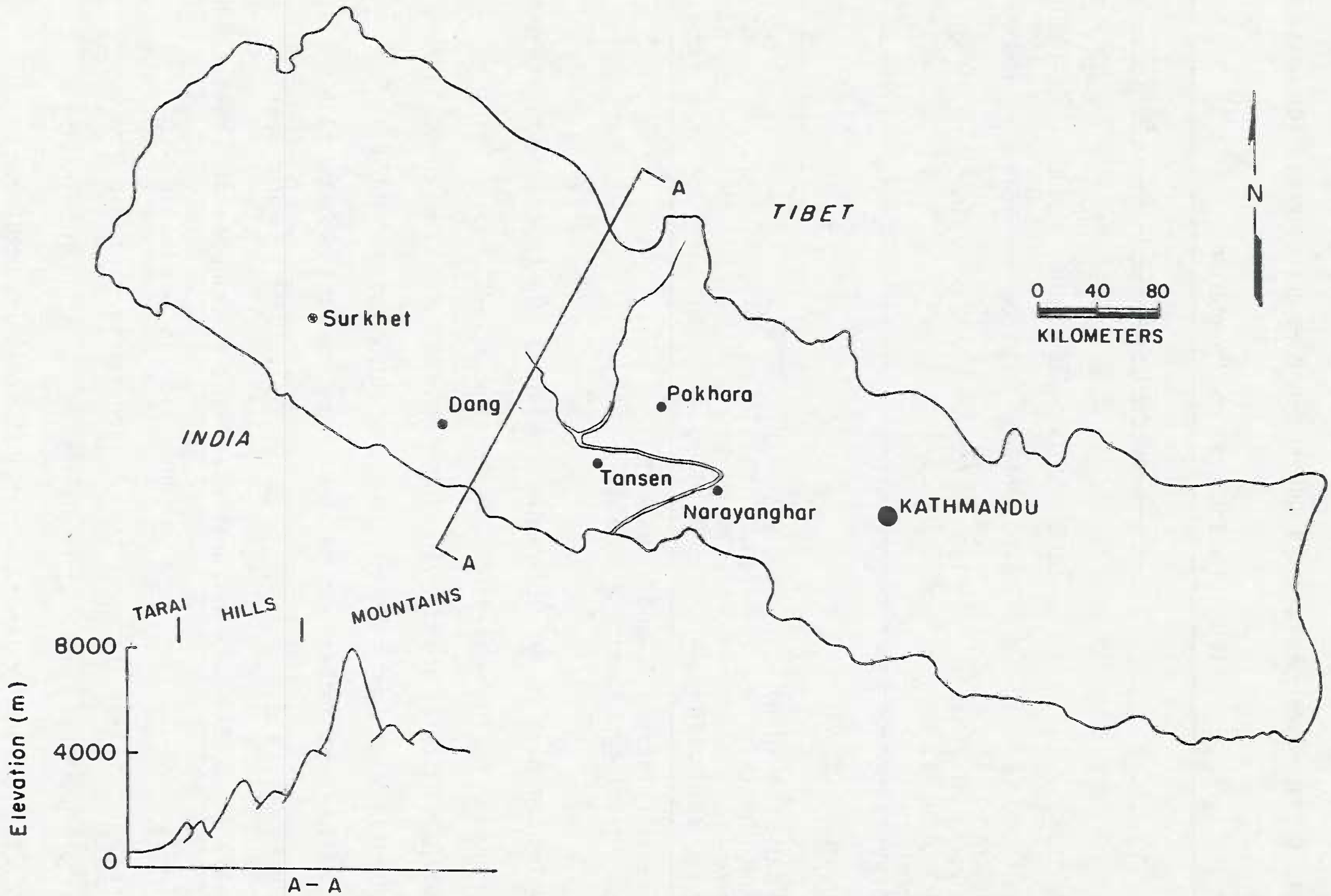

Figure 1.1 Nepal

yields a population density per square kilometer of cultivated land of 1246 and 1536 respectively, among the highest densities in the world. The Asian

Table 1.1 Land Area and Population

	WEC Study			ADB Study	
Land Area	Tarai	Hills	Mountains	Tarai	Hills & Mountains
Area (1000 ha.)	3400	8630	2120	3243	10857
Distribution (%)	24	61	15	23	77
Cultivated (1000 ha.)	1600	650	32	1600	1500
Distribution (%)	70.1	28.5	1.4	51.6	48.4
Potentially Arable (1000 ha.)	2050	650	32	-	-
Population					
Population (million)	5.9	8.1	0.5	5.8	9.9
Distribution (%)	40.7	55.9	3.4	37	63
Per km^2	174	94	24	179	91
Per km^2 cultivated land	369	1246	1563	364	658

Sources: Columns 1,2, and 3: WEC, 1981.
Columns 4 and 5: ADB, 1982.

Development Bank study, citing estimates made by the task force on land use appointed by the National Planning Commission in 1980, reports that 1,500,000 hectares are cultivated in the hills and mountains combined for a population density per square kilometer of cultivated land of 658.

The fact that these estimates differ by more than a factor of two is indicative of the state of land-use data in Nepal. Both sets of figures, however, make the point that arable land is an extremely scarce resource in the hills. Individual family landholdings average less than 0.4 hectare (1 acre), and the typical fragmented hill farm can hardly support the family that is dependent upon it. Under the pressure of population growth, cultivation has been extended to marginal lands not suitable for crop production. The Nepal Agriculture Sector Strategy Study (ADB, 1982) reports that per capita food production has decreased during recent years. Even more serious is the study's evidence that yields of maize and rice, the two major hill crops, have been declining (see Table 1.2). While in 1966 Nepal was reported to have the highest rice yield among the countries of South Asia, it now apparently has the lowest (ADB, 1982). Yields in the other countries of Asia have increased while those in Nepal have stagnated.

Table 1.2 Average Yield of Major Cereal Crops during 1960s and 1970s (mt/ha)

Crops	Ave. Yield During 1961/62 to 1970/71	Ave. Yield During 1971/72 to 1980/81
Rice	1.92	1.88
Wheat	1.20	1.14
Maize	1.89	1.69

Source: Asian Development Bank, 1982

The scope and rate of environmental degradation in the hills of Nepal has been graphically described in a number of publications (e.g., Eckholm, 1978 and Rieger et al, 1976), as well as in countless development project documents, and also dramatically portrayed in the film, The Fragile Mountain (Nichols, 1982). Bajracharya (1981) has concluded, based on research done in the hills of eastern Nepal, that the main cause of deforestation and erosion is the ever more desperate quest for food as cultivation has been extended onto steeper, more unstable slopes. This attempt to expand the area under production not only results in less efficient production; it also leads to the destruction of more productive land, as well as human life, at lower elevations as a result of landslides and flooding caused by the rapid run-off of monsoon rainfall from deforested slopes.

In the long run, the solution may be to follow principles of comparative advantage, producing most of Nepal's grain on the _tarai_ and horticultural and animal products in the hills. The Nepal government's Fourth and Fifth Five-Year Plans (1970-75 and 1975-1980) advocated this approach. In the Fourth Plan, the National Planning Commission states:

> The hilly region, in general, is a food deficit area while the _Tarai_ is a surplus area. Therefore, encouragement should be given to the production of commodities other than cereals in the hills. If the rules of comparative advantage are used, this should, in turn, help to increase the standard of living of the local people (National Planning Commission, 1972:132).

For the foreseeable future, however, the hill population will have to produce the bulk of its own food, including grains. Several factors lead to this conclusion. People who are accustomed to growing their own food are reluctant to shift to cash crop production and rely on others to produce their vital subsistence food crops. This is especially true in the Nepal hills where the risk of producing and marketing horticultural products is great. The lack of transportation facilities from the hills to the _tarai_ makes it difficult to deliver fruits and vegetables to markets in the _tarai_ on time and in good condition. Established grades and quality standards as well as prices are lacking for these products. Hill farmers who would supply products to the _tarai_ markets face stiff competition from Indian suppliers who do not have the same transportation problems in serving these markets. There is little significant potential for cash income-generating activities in the hills which would enable people to purchase food imported from the _tarai_.

These factors, coupled with the negligible scope for bringing additional land in the hills under production, render the intensification of agricultural production on currently cultivated land in the region an objective of paramount importance. The government of Nepal has realized this, and "the Sixth Plan (1980-1985) is, therefore, geared to strengthen the hill economy and to conserve and develop the natural resources for maintaining a reasonable balance between population and environment" (National Planning Commission Secretariat, 1979:10).

The lack of adequate supplies of water has been identified as a major constraint to the increase of food production in Nepal. Nepal has a monsoon climate, where more than 75 percent of the rainfall is concentrated in the period from mid-June through September. With little precipitation between October and May, areas without irrigation facilities are prevented by lack of water from multiple cropping even though the temperature would allow it. This was dramatically evident in the area of one of the field research sites. Farmers in one village were growing three irrigated crops a year, while those in a village directly across the river, where there was no irrigation system, were able to grow only one rainfed crop annually.

Irrigation has proved to be one of the most certain means of increasing agricultural production in areas where rainfall is not adequate in quantity or timing to make maximum use of the growing seasons. There are at least four different ways in which irrigation can increase production:

1. It provides insurance against crop loss due to failure or poor timing of the monsoon rains.

2. It can enable multiple cropping where the rainfall pattern would be sufficient for only one.

3. Timely provision of the right quantities of water is essential for the efficient use of other modern inputs such as fertilizer and management-responsive varieties.

4. By reducing the risk of crop failure due to drought, it can induce farmers to apply higher levels of complementary production inputs such as fertilizer.

The government of Nepal has targeted the development of irrigation systems as a major element in efforts to intensify production and increase output. While the development of irrigation is a necessary condition for intensification of agricultural production, the mere construction of diversion structures and canals does not necessarily result in the expected increases in production. A survey of irrigation projects constructed by the government of Nepal and donor agencies reveals that many of them irrigate much less than the area for which they were designed, and the estimated cropping intensities have not been achieved. In many cases, less than half of the planned command area has received water (WEC, 1981). According to WEC, "The reasons for this state of affairs are ill-conceived, poorly designed and incomplete development, unsound construction, deficient operation and negligable and untimely maintenance" (WEC, 1981:iv-v). Nepal is not alone in this situation--"planners are increasingly concerned about the low performance level of Asian irrigation systems, especially many of the larger, state-run systems" (Barker et al., 1984:2).

With the limited resources that Nepal has, it is essential that they be used efficiently. The need for efficiency in the use of land and water resources often requires intensification of the management of irrigation systems. This is recognized as a necessary complement to appropriate technical design and construction and, to some extent, can substitute for these capital investments (Levine, 1979; Chambers, 1980).

Not only is cultivable land scarce in Nepal, but so are (1) capital and (2) professional technical and managerial resources of the central government. The difficulties of transportation and communication in the hills and the fact that feasible irrigation sites are small and scattered make it difficult and costly for the central irrigation bureaucracy to develop quickly and manage efficiently the existing irrigation systems throughout the region. As a Department of Irrigation official has said, "It has been felt that constant watch has to be placed for successful operation and maintenance of hill projects. This, too, involves high operation and maintenance costs" (B.K. Pradhan, 1976).

There is a growing awareness on the part of many central governments of the need to mobilize local resources for development, and this is true of the government of Nepal. In the Basic Principles of the Sixth Plan, Nepal's National Planning Commission states:

> According to the highest priority given to the irrigation programmes within the Agriculture sector, only government efforts will not be enough to launch the massive programmes. Hence, maximum importance will be given to peoples' participation (1979:38).

Most government bureaucracies, however, are not accustomed to operating in such a fashion so as to encourage and facilitate peoples' participation. According to B.B. Pradhan (1981:66), "The fundamental shortcoming in agricultural planning in Nepal is the top-down approach which has a total lack of understanding and appreciation of the local situation. The farmer who is the principal figure in the process of agricultural development is virtually ignored." He concludes that, "In these circumstances, farmers' participation in the development process is just wishful thinking."

The irrigation sector in Nepal is unique in that an estimated 80 percent of the irrigated area is serviced by systems which are managed by the farmers themselves, rather than by government officials. In the hills, an estimated 150,000 hectares are irrigated by farmer-managed systems compared to 10,000 hectares by systems constructed and operated by government agencies. For the tarai, the figures are 250,000 and 90,000 hectares respectively (Water and Energy Commission, 1981).

An estimated total of 300,000 hectares are irrigable in the hills, i.e., 140,000 hectares in addition to the 160,000 already irrigated (WEC, 1981). In many places where there is potential for irrigation by gravity flow, however, the farmers have already developed the irrigation resource to some extent. Consequently, farmers have experience with irrigation management and have derived traditions of water rights and rules for distributing water, maintaining the system, mobilizing resources, and managing conflicts. Farmers' knowledge of the local environment, their experience with the construction and management of irrigation systems, and the local organizations developed for carrying out these activities represent potentially valuable resources for utilization in further irrigation development. However, all too often, governmental concerns for peoples' participation and the mobilization of local resources for irrigation projects are limited to getting economic resources such as contributed labor for construction and maintenance, land provided for rights of way, and user fees in cash or kind (Levine and Hart, 1981).

While there are thousands of farmer-managed irrigation systems in the valleys of the hill region of Nepal, it has been only in the 1980s that they have been included in estimates of irrigated area and an effort made to quantify the area served by such systems (WEC, 1981; Asian Development Bank, 1982). Most references to them have dismissed them as inefficient and technically inappropriate, reflecting the professional technicians' bias for permanent structures of concrete and steel. Yet studies of farmer-managed irrigation systems in the Philippines (Lewis, 1971; Siy, 1982), Indonesia (Geertz, 1980), Thailand (Tan-kim-yong, 1983), Sri Lanka (Leach, 1961), and Peru (Mitchell, 1976) have revealed many of them to be extremely effective and equitable. This performance is due to the irrigators' intensive management efforts and, in some cases, the unique, indigenous technologies employed.

Despite the widespread existence of farmer-managed irrigation systems in the hills, little is known about how they are operated and how effective they are. B.B. Pradhan laments the fact that "as important as the traditional irrigation is in Nepal's agriculture, no study has been made of this sector" (1982:19). He advocates the use of existing irrigation organizations in further irrigation development and suggests that the lack of information regarding traditional irrigation is the reason that project formulators and implementors have not been doing this. Upadhyay and Koirala also say that there is a need to learn from farmer-managed irrigation systems in the hills because "there exist effective water management systems in certain hill pockets which could be replicated in other areas" (1981:107).

1.2 Focus of the Research

Given (1) that in many places where irrigation can be developed in the hills, farmers are already irrigating to some extent, and (2) that the government has a stated policy of utilizing local resources in irrigation development, this research project has focused on farmer-managed irrigation systems in the hills.[2] Our assumption was that at least some of the farmer-managed systems, like those observed in other countries, would prove to be effective and efficient and that knowledge could be gained from a study of how farmers manage irrigation that could be useful in future irrigation development by the government.

Two questions guided the development of a research focus on farmer-managed irrigation systems: (1) how effective are these irrigation systems, and (2) are there lessons to be learned from these systems that will enable better utilization of government resources in irrigation development. The notion of applying learning from observation of farmer-managed systems to future government efforts in irrigation development raises numerous questions. How do these systems function? What factors determine the operational methods, management practices, and technologies that farmers have evolved and employ? How effective are they in using scarce production resources, both water and land? The general objective of the research project was to understand the technologies and management organizations of these systems and to make an evaluation of their performance in terms of efficiency and equity of irrigation resource use.

---

[2]It was assumed in the formulation of the research that more experience and richer diversity in farmer-managed irrigation would be found in the hills than the <u>tarai</u>. It was also expected that farmer experience would possibly have the greatest direct applicability for irrigation development in the hills. In the course of the study, it was discovered that there are many, and some large (more than 5000 ha.), farmer-managed irrigation systems on the <u>tarai</u> (WEC, 1981). The present study could not be extended to investigate systems on the <u>tarai</u>, but it would be extremely useful to examine the effectiveness of the large and intricately organized systems there as reported by Prachanda Pradhan (1983).

1.3 Interdisciplinary Nature of the Research

This study was conducted jointly by an agricultural engineer (Robert Yoder) and myself (agricultural economist). Both were Ph.D. candidates in their respective disciplines and had previously worked together in Nepal on industrial and rural development projects. From the inception of the idea of doing joint field research and definition of the study, through data collection, analysis, and write-up, it has been truly a team effort. The constant, close interaction of two people from different disciplines with previous experience working together on development projects in Nepal has certainly broadened the horizon of enquiry and enhanced the level of understanding gained through the research. While the field work and analysis were divided along disciplinary lines as much as has been possible and practical, the field methodology was developed jointly, and both researchers were conversant with all aspects of the data collection. This allowed for mutual assistance at times of peak data-collection activity, enabling a broader scope of study. In the analysis and writing, both benefited from the critical review of the other.

The interdisciplinary nature of the research and the breadth of understanding gained was expanded by a parallel and closely coordinated research project conducted by Dr. Prachanda Pradhan, a social scientist. Dr. Pradhan studied the organizational aspects of both hill and tarai irrigation systems, including both farmer- and bureaucratically-managed systems. Included in his sample were three of the primary research sites of this study. In addition to sharing his information, he added valuable insight and understanding through frequent discussions both in the field and in Kathmandu.

1.4 Dissertation Objectives and Focus

The broad questions and objectives of the research have been somewhat (1) narrowed to make them more manageable and (2) separated to fit better the requirements of writing dissertations in the two different disciplines. The objectives of this dissertation are to:

1. Describe the different irrigation management organizations observed and the ways in which they carry out irrigation management activities.

2. Investigate the management of irrigation systems under differing water supply conditions to analyze (a) the relationship between water supply and the intensity of irrigation system management and (b) the impact of water supply on the structure of the irrigation organizations.

3. Analyze the impact of different water allocation principles, e.g., water allocated in proportion to the area irrigated and water allocated by purchased shares, on the efficiency and equity of the use of irrigation resources.[3]

As implied by these objectives, the focus of the dissertation is on irrigation management institutions. Institutions of two different types have been defined (Uphoff, 1984). Significant practices or relationships within a

---

[3]The specific objectives of Robert Yoder's thesis are to:

1. Describe the range of technologies, organizations, and methods of operating and maintaining irrigation systems that are employed by farmers, i.e., identify the farmer resources (technology, skills, knowledge, and labor) that have gone into the construction, operation, and maintenance of their irrigation systems.

2. Make field measurements of the water budget components and compute the relative water supply to measure the effectiveness of farmer-managed irrigation systems.

3. Evaluate the effectiveness of several farmer-managed irrigation systems in meeting local equity criteria and for efficiency in using the land and water resources.

4. Analyze the need for different technologies and levels of organization among systems with respect to their environmental settings.

society or culture are one kind of institution, and the second type are established organizations, particularly of a public nature. Examples of the first type of institution are land tenure systems and customary labor exchange arrangements. Many different organizations such as cooperatives, local government, banks, etc. are institutions of the second type.

Institutions of both kinds contribute to production and development processes in several ways. They facilitate the aggregation of resources beyond an individual's capacity and the application of those resources to the solution of problems for the benefit of many. They remove uncertainty by the predictability of behavior that they encourage and enforce in different spheres including the distribution of benefits from public investments or resources. This can result in higher levels of investment and, thus, production (Uphoff, 1984).

1.4.1 Farmer Irrigation Organizations

Farmer-managed irrigation systems, which are dependent for their operation and maintenance on the contribution of resources from many people and which allocate and distribute water to many farmers' fields, require some organization for their management, though it need not be formal. In the hills of Nepal, farmer-managed irrigation systems, having developed in response to varying local conditions, exhibit a diversity of organizational forms and principles. These systems tend to be management-intensive and employ technologies that are more labor-intensive than capital-intensive. Many of them have been in existence for generations, even centuries, but little is known of how they operate. A study and description of some of the different organizational forms, as stated in objective one, will yield information which should be useful in carrying out further irrigation development with an emphasis on peoples' participation.

A useful and common way to organize a discussion of the management of irrigation systems is to delineate the tasks that must be successfully accomplished if the water resource is to be effectively used in agricultural production. Several schematics of irrigation management activities have been proposed (Coward, 1980; Kelly, 1983; Uphoff, Meinzen-Dick, and St. Julien, 1985). The one developed by Uphoff et al. is the most comprehensive and analytical. Three different sets of activities are distinguished on the basis of whether they deal directly with (1) the water, (2) the physical works of the system which control the water, or (3) the organization that controls farmer behavior and the physical system, and hence the water. These three sets can be considered as different dimensions of an irrigation system, and each includes four activities. Figure 1.2 presents the three sets of management activities in the form of a three-dimensional matrix consisting of 64 cells.

The activities which focus on water use include: (1) acquisition, (2) allocation, (3) distribution, and (4) drainage. Water must first be acquired by some means such as dams, diversions, or wells. Right of access to portions of the water needs to be allocated among farmers. The water is distributed among users at certain places (specific fields) in certain amounts at certain times. Drainage removes any excess water. An explanation for the inclusion of both allocation and distribution as water-use activities is needed. The terms "allocation" and "distribution" are used interchangeably in much of the irrigation literature, but they have different meanings, and the distinction between them is certainly important in the farmer-managed hill systems in Nepal. Water allocation refers to the entitlements to water from

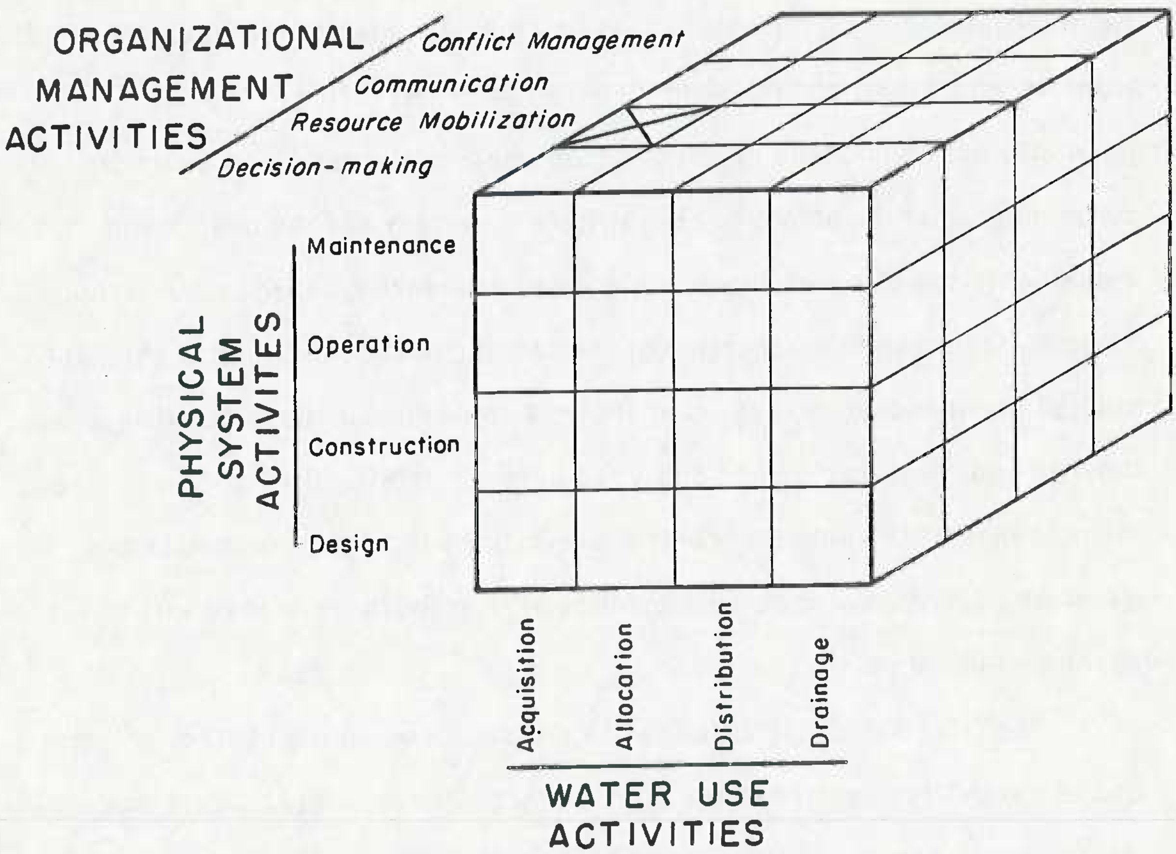

Figure 1.2 Irrigation Systems Activities Matrix
(adapted from Uphoff et al, 1985)

an irrigation system and the principle or basis by which these are shared among the irrigators. Water distribution refers to the physical delivery of water to the fields. This actual distribution may or may not be in accordance with the allocation scheme depending on how effective the organization and physical structures are.

Uphoff et al list four activities which concern the physical structures for water control: (1) design, (2) construction, (3) operation, and (4) maintenance. While design and construction have important implications for the management of an irrigation system (not all types of management are possible with all kinds of system design and construction), they are generally not considered ongoing management activities. The decision concerning whether or not to rehabilitate a system and the design and implementation of rehabilitation might be considered management activities. Original design and construction of the farmer-managed systems that were studied occurred so long ago that little is known about these activities, and they will not be described or analyzed in much detail. Operation and maintenance of the physical control structures to acquire and distribute water are extremely important management activities and they will be described in detail.

The first set of activities in the matrix focus on the control of water, and the activities applied to the physical structures of the system make possible this control of the water to a greater or lesser degree. There are also certain organizational activities which establish social control to make human behavior predictable and effective. The four organizational activities are: (1) decision making, (2) resource mobilization, (3) communication, and (4) conflict management. These may focus on the water, e.g., decision making about acquisition, allocation, distribution, and drainage. They also apply to the physical structures, e.g., communication concerning operation and maintenance. Organization is a variable, not a given. It can be formal or informal, continuous or intermittent. One can say that organization for irrigation management exists to the degree that these activities of decision making, resource mobilization, communication, and conflict management occur.

The cells of the matrix in Figure 1.2 represent the interaction or relationships among the three dimensions in the management of an irrigation system. Not all cells will be equally important in every system. In the extremely well-drained soils of the river terraces in the hills of Nepal, for example, drainage is not an important concern of an irrigation organization.

An especially important cell in these systems, highlighted in Figure 1.2, is the one representing the combination "Acquisition-Maintenance-Resource Mobilization." Resource mobilization for maintenance of the physical structures for acquisition of water is a critical activity in the hill environment. Even though not all cells are equally important, the framework represented by this matrix provides a useful checklist as one describes and analyzes an irrigation system. The description of irrigation organizations in Chapter 3 will be organized according to the activities in this three-dimensional matrix.

1.4.2 Management Intensity and Organizational Structure

Effective management can, to some degree, substitute for costly capital. An irrigation management organization which can quickly organize large amounts of labor to maintain structures built of stones, mud, and sticks can manage without permanent cement and steel weirs, desilting chambers, and cement-lined canals. Levine (1979a) has referred to this as a trade-off between "software" and "hardware."

Management and water are also substitutable to a certain extent (Levine, 1979b). The same yields that are obtained with a relatively high supply of water can be achieved with less water and more intensive management. It was hypothesized under objective two that the management effort employed and, consequently, the degree of formality of irrigation organizations would be inversely correlated with the available water supply. If the water supply were scarce, more intensive effort would be required to manage the water efficiently and the organization would be more formally structured, and vice versa. By examining irrigation systems with differing water supplies relative to the area of irrigable land, it was thought that conclusions concerning the appropriate intensity of management for different water supply conditions could be drawn.

Increasing management intensity is a term that is not particularly easy to conceptualize and is even more difficult to measure. Levine[4] has defined "increasing management intensity" as management that responds to or incorporates more variables into decisions regarding the operation of the system. Instead of having a fixed, predetermined plan of operation, the system is operated in response to observed conditions.[5] These conditions, such as soil type or crop grown, may not be the same in all parts of a system. Some soils and crops need more water than others to produce a good yield. Conditions may also change during a season. More intensive

---

[4]Personal communication, February 1985.

[5]Levine has referred to systems with a fixed, predetermined plan of operation as "administered" systems in contrast to "managed" systems which are operated in a manner that is responsive to information received from the environment, including the farmers (personal communication).

management would take into account these differences instead of treating the whole system as homogeneous.

The ultimate objective of intensifying management is to increase the efficiency and/or equity of utilization of irrigation resources. Increasing "efficiency," as used here, means increasing the economic productivity of the water and land resources. In a subsistence economy where limited land and water resources are constraints to further production, efficiency in physical productivity and in economic productivity are nearly the same. An important aspect of this will be seen to be that of expanding the area that is being irrigated by the supply from a given source.

There are several elements to the equity concept employed here. One is that all farmers within a system receive the water to which they are entitled, i.e., that there is no disparity between service to the farmers at the head of the system near the source and those farther away in the tail. A second is that there is proportionality between the share of benefits received by individual farmers and the portion of costs of operation and maintenance borne by them. A third element relates to access to irrigation resources. In many irrigation systems the area that may be irrigated by the system is strictly defined, and the rights to the water are controlled by farmers with fields within that area. It may be that there would be sufficient water to irrigate a considerable amount of land outside the designated area if a more intensive form of management were adopted. If the system allows for expansion of the area that is irrigated, through some transfer of water rights such as selling or renting, this is considered more equitable than if persons can get access to irrigation only by buying some of the land that is already being irrigated. This issue of the transferability of water rights (i.e., allowing for expansion of the area irrigated) also, of course, has important implications for the efficiency of irrigation resource use.

If an irrigation system is to be operated in response to more variables, additional control over the water will be required, and increasing control is one of the primary purposes of increasing the intensity of management of an irrigation system. Often management intensity is thought of primarily in terms of distribution of the water within an irrigation system. Continuous-flow distribution, whereby water is continuously supplied to all parts of the system, is considered to be the least intensive form of management of distribution. The level of control achieved over the water distributed under continuous flow can be increased through the use of structures for measuring the discharge as it is apportioned off from the main canal into secondaries and from these into field channels and field turnouts. Structures such as gates, division boxes, and proportioning weirs, if they are operated properly, give more control over the distribution of the water than completely uncontrolled bifurcations. Introduction of rotational distribution according to predetermined schedules is generally considered to be a more intensive form of management of distribution, providing more control over the water than continuous-flow. Distribution in response to farmers' demand is considered to be still more intensive management of distribution as the system's delivery of water is responding to more variables, i.e., the farmers' demand for water which may vary greatly among farmers.

The three-dimensional matrix of irrigation management activities indicates that distribution is not the only activity that is intensified as management is increased. From the organization's standpoint, it is the organizational management activities that are intensified. Some or all of these, i.e., decision making, resource mobilization, communication, and conflict management, must be done to a greater degree to enable intensification of the water-use and physical system activities.

Increasing the control over the supply includes augmenting the amount and/or the reliability of the supply through intensified efforts in the acquisition of water. The major management activity concerning the physical structures which affects the acquisition of water is maintenance. By doing more and/or better maintenance of diversion structures and conveyance canals, a greater supply of water can be delivered more reliably. But doing more maintenance requires more intensive mobilization of resources (labor and/or cash) from members. This in turn requires more social control in the form of records of members' contributions and sanctions for failing to contribute, which means the organization must be stronger. Decision making is needed to decide what maintenance to do and when to do it. More intensive communication is a must. If more maintenance to increase the supply and/or make it more reliable is to be done, a communication network to inform the farmers when they have to go to work on the system is essential. This is particularly critical in times of emergency maintenance. An early warning system of the need for maintenance is essential, as well as a method of quickly communicating this fact to the member farmers. If farmers are expected to do more work to maintain the system, there may be more of a tendency to be absent. This may lead to conflict as some members resent the irresponsibility of their lazy neighbors. Means of conflict management, including sanctions and enforcement procedures, are essential.

To utilize water more efficiently requires what can be termed as more management-intensive principles of water allocation. An allocation principle which allocates to every field within the fixed area served by the system an amount of water proportional to the percent of that area each occupies is not a management-intensive allocation principle. It does not take into account the fact that some fields might need more water and others less to grow a crop without stress because of differences in soil type, the crop being grown, quality of land preparation, and depth of the water table. In addition, if there were an opportunity cost associated with the marginal use of water, i.e., if each unit of water used cost the farmer something either in the form of a payment or income foregone from the sale or rental of some of his water, some farmers might be willing to make do with less water than others.

A water allocation principle which allows for the transfer of water rights among farmers, both those who are already members of the organization and nonmembers who would like to acquire water rights, is a more management-intensive allocation principle. It allows the allocation and use of water to respond to a number of factors and also provides a mechanism for expanding the area irrigated. One principle of allocation which does this is the allocation of water rights within a system by the sale of shares. This requires careful record keeping of all members' water allocations as well as the ability to adjust the distribution pattern in response to changes in the allocation. Expansion of the irrigated area may have implications for the type of distribution that is needed to effectively supply each farmer his allocation and for the effort to increase the supply through maintenance and/or rehabilitation. Decisions as to whether the organization or individuals should sell shares, as well as establishment of the price of shares, are needed. Communication concerning changes in the pattern of alloction is needed. Allowing transfer of water allocation could lead to more conflict as buyer and seller disagree over how much water is to be transferred, necessitating more conflict management.

More intensive management of the water may mean that some or all farmers will have to make do with less water. This will not be the case if the focus of the increased management intensity is on water acquisition. It will, however, be true if more intensive management of the distribution is sought because the allocation has been changed to allow for expansion of the area irrigated or because the supply in the source has been reduced by drought. Under such conditions, the potential for conflict is greatly enhanced as farmers are tempted to try to ensure the adequacy of their supply by stealing water. More intensive efforts in conflict management may be required if the system is to function efficiently and equitably.

The management of an irrigation system, thus, includes a multiplicity of activities. Nearly all efforts to increase management intensity will require the utilization of some resources. In many irrigation systems, the resource expended is often labor. Capital and information are other resources which are often needed. However, it is not always possible to quantify, in a meaningful way, the additional resource expenditure required to intensify irrigation management. In the quantitative analysis in this dissertation, it was not possible to incorporate all of the activities which have been elaborated above. The analysis was limited to the management activities for which data were available, and exactly which activities were included will be made explicit in the different analytical sections.

The fact that a greater intensity of management requires more social control to make the irrigators' behavior more predictable and effective was expected to have an impact on the nature and level of structure of the farmers' organization for managing the irrigation system. It was expected that in systems where the water supply was scarce relative to the area that could be irrigated, the management organization would be more highly structured to facilitate more social control and the more efficient use of a scarce resource. In contrast, systems with abundant water supplies were expected to exhibit a lesser degree of organizational structure.

1.4.3 Principle of Water Allocation

While conducting field research, it became apparent that the principle of water allocation is an important institution in irrigation systems which has potentially significant implications for the efficiency and equity of utilization of the irrigation resources. Allocation, the distribution of water rights or entitlements to water among farmers, consists of two dimensions: (1) differentiation of those fields or farmers who have access to water from the system from those which do not, and (2) distribution of the entitlements to amounts or shares of water among the fields or farmers with rights to it.

Two distinctly different principles of water allocation were observed among the irrigation systems studied. Under one, the area with access to water has been demarcated and water is allocated among the fields according to the proportion of the total command area occupied by each field. For example, a field whose area equaled one-tenth of the total command area would be entitled to one-tenth of the flow in the system. The other principle of water allocation apportions water to farmers according to the resources each user contributes or has contributed to the creation and upkeep of the system. A farmer who has contributed five percent of the resources, through purchase of five percent of the shares, is entitled to five percent of the flow in the system irrespective of the amount of land he is farming. The separation of ownership of rights to water from ownership of land and the fact that water rights can be transferred between farmers through sales are extremely critical features of this second principle of allocation. It is the hypothesis of this analysis that allocation according to "purchased shares" results in more efficient and equitable use of irrigation resources than allocation "in proportion to area irrigated."

1.5 <u>Structure of the Dissertation</u>

Following this introductory chapter, Chapter 2 will describe the sources and the process of data collection in the field. It will also discuss some of the methodological problems in doing field research on irrigation systems. Reasons for selecting the particular research sites and the procedure for selecting the sample fields and farmers will be presented. The data that were collected and the procedures for collecting data will be described. These include water measurements, soil surveys, crop cut data, farm management surveys, general socioeconomic data, and irrigation organization information.

Chapter 3 will describe the four primary research sites of Argali, Chherlung, Majuwa and Thambesi. The description will include the location, ethnic composition, cropping pattern and farming system, and number and size of irrigation systems and organizations. Some analysis of agricultural production practices will be presented in this chapter. Since the focus of the study is irrigation institutions, a fairly detailed description of the irrigation systems studied will be presented. The focus of the description will be the farmers' irrigation organizations, and the discussion will be organized around the irrigation management activities outlined in the discussion of the three-dimensional matrix above. Some description of the technologies employed and their relationship to the accomplishment of the management activities will be included. The types and amounts of resources and the way in which they are mobilized will be described.

The relationship between water supply and management intensity will be analyzed in Chapter 4. The chapter will include a section describing the different supply-enhancing and demand-diminishing water management activities. A descriptive analysis of management of water distribution under different water supply conditions will be presented. A linear programming model of an irrigation system has been developed for the analysis. Water management activities, along with crop production activities, will be incorporated in the model. The model will be verified by comparing the activities specified in the computer-derived solution with the observed activities in one of the Argali irrigation systems, the one for which the most data are available. Changing the water supply in the model will enable an analysis of the relationship between water supply and management intensity.

In Chapter 5 the factors contributing to the levels of organizational structure in the farmer-managed irrigation systems will be analyzed. In particular, the relationship between resource mobilization and the structure and performance of the organization will be analyzed. One hypothesis is that the amount of resources needed to be mobilized for water acquisition is the dominant factor determining the structure of the organizations. A second hypothesis is that water distribution is done more effectively and equitably in irrigation systems which must mobilize a significant amount of resources from their members for water acquisition than in those systems where water acquisition requires little effort on the part of farmers.

Chapter 6 will begin with a short review of the literature on property rights in water in irrigation systems. This chapter will focus on the "security" factor of property rights, i.e., the role of property rights in providing assurance of expectation that individuals or groups of farmers will reap the benefits from their investments to develop an irrigation system. Information concerning this aspect of water rights in the hills of Nepal will be presented and discussed.

In Chapter 7 the impact of different water allocation principles on the efficiency and equity of irrigation resource use will be analyzed. The literature on principles of water allocation will be reviewed, and the importance of "flexibility" or "transferability" of the allocation will be emphasized. Data from the research sites will be used to test the hypothesis that allocation according to "purchased shares" leads to more efficient and equitable use of the irrigation system than allocation "in proportion to land area served." Modifications to the linear programming model developed in Chapter 4 will be made to allow for the incorporation of these two different principles of water allocation, and their influence on the expansion of land area irrigated and the level of production will be analyzed.

Chapter 8 will summarize the major findings. Implications of the research for irrigation development strategy and policy will be drawn. Finally, an attempt will be made to fit the irrigation observed in the hills of Nepal into the broader context of the evolution of irrigation in Asia.

CHAPTER 2: FIELD DATA COLLECTION

2.1 Problems in Doing Research on Irrigation Systems

The focus of this research is at the irrigation system level. Research on irrigation systems, particularly in a developing country like Nepal, presents a number of practical and methodological problems. With the focus of research being irrigation organizations and systems, one would ideally like to study a large number of irrigation systems. For statistical analysis of system variables such as relative water supply, cropping intensity, resources mobilized, number of farmers, and area irrigated, a fairly large sample would be required. This is especially true in Nepal where there is a great deal of diversity in environmental conditions. But the difficulties of travel and the amount of information needed to understand the management of a single system make it virtually impossible to investigate a large sample of irrigation systems.

To understand the dynamics of irrigation and agricultural development, one would like to have time-series data concerning a number of variables including area irrigated, crops grown, stream and canal flows, labor and cash investments, rates of input use, crop yields, prices, population, and rainfall. For farmer-managed irrigation systems in Nepal, very little of these data are recorded. Typically the researcher must make do with one year's measurements and farmers' recall of past years, and this was the case in the present study. Time-series data from farmers' recall can be enlightening concerning the process of change and the general time frame within which it has taken place. These data, however, do not lend themselves to precise quantatative analysis.

The ultimate purpose of investments in irrigation is to increase production; therefore, crop yields are an important measure of irrigation performance. Evaluating the effect of irrigation on agricultural production, however, is not a straightforward task. Crop yields are not determined solely by the water supply, but are also affected by other factors such as fertilizer, labor, land preparation, timing of planting, rate of seed use, disease, insect-damage, and weather. Crop yields are, thus, a function of individual farmers' decisions about use of technology and allocation of resources and are not, therefore, a direct measure of irrigation system performance.

Isolating the impact of irrigation on yields is difficult. An improvement in water supply will have little effect on the level of yields if management-responsive varieties and increased amounts of fertilizer are not also introduced. At the same time, the use of these potentially high-yielding varieties and increased amounts of fertilizer results in little improvement in yields if adequate water is not supplied at the right time. Knowledge of what is happening at the field level is required to know whether low yields are due to poor irrigation performance or to some other constraint. This requires very intensive data collection within a single irrigation system, compounding the problem of investigating a large number of systems.

Theoretically, to evaluate the contribution of irrigation to crop yields, one would estimate a production function with water as one of the variable inputs affecting the level of yields. To use this production function concept to empirically analyze irrigation performance, one needs an estimate of the functional relationship of water and other inputs to crop yields as well as field-level measurements of water supplied, inputs applied, and yields. The nature of the production function for various crops has been estimated under controlled conditions (Hexem and Heady, 1978; Minhas et al, 1974).

Two types of water measurement problems confound the estimation of a water response function based on data from farmers' fields in a country like Nepal. These problems render measurement of the actual amount of water available to the plant, if not impossible, certainly impractical and infeasible under research resource constraints. Data on application of other inputs and yields can and must be collected at the field level. The first problem concerning measurement of water applied to individual fields is that it cannot be done for a sufficient number of fields to make statistical estimation possible. The technical difficulties and expense of making the measurements are too great.

Plants require water for growth, and this water in the plants must be continually replaced. Solar energy causes it to transpire from them. The second measurement problem is a result of the fact that not all of the water applied to a field actually reaches the root zone of the plants where it can be utilized. There are several ways that water is lost before it can be used by the plant. Some of the water applied to a field evaporates from the surface without ever reaching the plants' root zone. In the humid tropics, a reasonable approximation for the evapotranspiration demand (the water used up by evaporation and transpiration) for water is given by the rate of evaporation from class A evaporation pans (Svendsen, 1983).

Two other main sources of loss occur when irrigation by flooding causes some of the water to leave the root zone vertically through deep percolation and laterally by seepage. This seepage and percolation (S&P) element of the demand for water is much more difficult to determine. It is dependent on the soil type, depth to the water table, quality of land preparation, subsurface soil structure, and water application practices. These different factors can vary greatly within a small area, affecting how much of the water applied is actually available to the plants. Under the same application of water, plants in one field might experience yield-reducing stress while those in another receive more than enough to satisfy evapotranspiration requirements. "Thus even if it were feasible to measure the amounts of water delivered to individual fields, these measurements would not necessarily correlate well with the actual water input in the biological production process" (Small and Chen, 1984). Instead of trying to relate water input directly to yield, a more common practice is to attempt to measure water or moisture stress and its impact on yields. One must then analyze the relationship of irrigation distribution to observed stress.

An indicator frequently used in the evaluation of an irrigation system's performance is the efficiency of water use. Efficiency of water use, however, is a meaningful criterion of system performance only if water is a scarce and limiting resource. Thus, without additional knowledge about relative resource endowments and constraints to production, a simple technical efficiency analysis is not necessarily an appropriate measure of an irrigation system's performance. Before an irrigation system can be evaluated, one needs to determine the most limiting factors of production.

Related to this is the question of which type of efficiency criterion is appropriate for the analysis--technical, economic, or social efficiency. Technical efficiency measures of output/input ratios yield different results than economic efficiency measures of benefit-cost ratio, net present value, and internal rate of return. A social efficiency criterion will usually incorporate more concern for equity and the meeting of basic needs of the entire population and, as such, implies a different resource and benefit allocation. The objectives toward which the system is being operated will determine, at least to some extent, which is the most relevant criterion, although all three may be of interest. With the high reliance of the overwhelming majority of the hill population on subsistence agriculture for their livelihood, achieving the most widespread distribution of benefits from irrigation systems is an important objective.

An irrigation system is not merely a technical system consisting of dams, canals, gates, and other structures to control and deliver water to the fields. And the environment in which it is situated is not defined solely by the physical variables of climate, topography, soil types, and the amount and temporal distribution of the annual rainfall. "An irrigation system is simultaneously a hydrologic, engineering, farming, and organizational system" (Coward, 1980:16) and is located in a socioeconomic and cultural, as well as, physical environment. A system's performance is, thus, affected by many different factors. The theory and tools of any single discipline are insufficient for gaining a comprehensive understanding of the dynamic development and present operation of an irrigation system.

An engineer, economist, agronomist, sociologist, and anthropologist working in an interdisciplinary and interactive mode would provide the most complete analysis of an irrigation system. However, in research, financial and human resource constraints generally do not allow for the ideal research design (in terms of gaining the most comprehensive knowledge). This was true in the present study. But, as described in Chapter 1, the field research was conducted jointly by an agricultural engineer and agricultural economist, who, together with their families, lived for one and a half years in a village in the mid-hills of Nepal in which were located four farmer-managed irrigation systems. The interaction of each family member with neighbors in the daily activities of rural life contributed to an understanding of the farmers' practices, problems, and constraints.

In an attempt to satisfy the need to study a number of different irrigation systems as well as to understand the farm-level irrigation and agricultural practices, data collection was carried out at two levels. Intensive data collection was done on four sites for more than one year, while more extensive data collection enabled information to be gained about irrigation systems in ten other locations.

2.2 Selection of Research Sites

2.2.1 Selection Criteria

Several criteria guided the selection of sites for intensive study of farmer-managed irrigation systems. The most important was to select irrigation systems representing a spectrum of water supply conditions from scarce to abundant. A primary objective was to investigate different levels or intensities of management, and it was expected that different water supply conditions would result in different intensities. It was our hypothesis that the intensity of irrigation management would be inversely related to the amount of water available relative to the irrigable area. The lower the potential supply relative to the potential demand for it, the more intensive would be the irrigation organization's management to utilize the scarce water more efficiently, and vice versa. It was also expected that systems with different water supplies would exhibit a range of technologies associated with the need to use resources differently. Finally, to examine constraints to production, at least one site was needed where water was scarce and likely a constraint and another where water was abundant and, therefore, not a constraint.

A decision was made to focus on irrigation systems on the river terraces along the major rivers flowing through the mid-hills. These terraces are 50 to 150 meters above the major river beds and when irrigated are supplied by small side streams which flown into the river. The flow in these streams varies greatly because they are not fed by snow-melt but only by rainfall which is concentrated in the monsoon season. Because of the difficulty of delivering water to these river terraces, it was expected that some of the most innovative, indigenous technology would be observed in systems serving them. Figure 2.1 shows the profile of a typical river terrace formation.

River terraces represent the main, relatively flat areas of any size in the hills and, thus, present the major potential for developing additional irrigation. They are at low elevations and thus, are suitable for intensive cultivation. The fact that they are at relatively the same elevation reduces the variability in temperature, an important factor in agricultural production.

Preference was given to areas having large or multiple irrigation systems over sites with only a single system or small ones. Multiple systems in a single site made it easier to gather information on more irrigation organizations, and it was expected that larger systems would exhibit more formal and complex organizational forms which would have more applicability to further irrigation development.

Another consideration was the availability of cadastral survey maps and land ownership records. Cadastral mapping of all of Nepal has been underway for some years, but is not yet complete in all of the hill districts. Sites were chosen for which this information was available, and it proved invaluable.

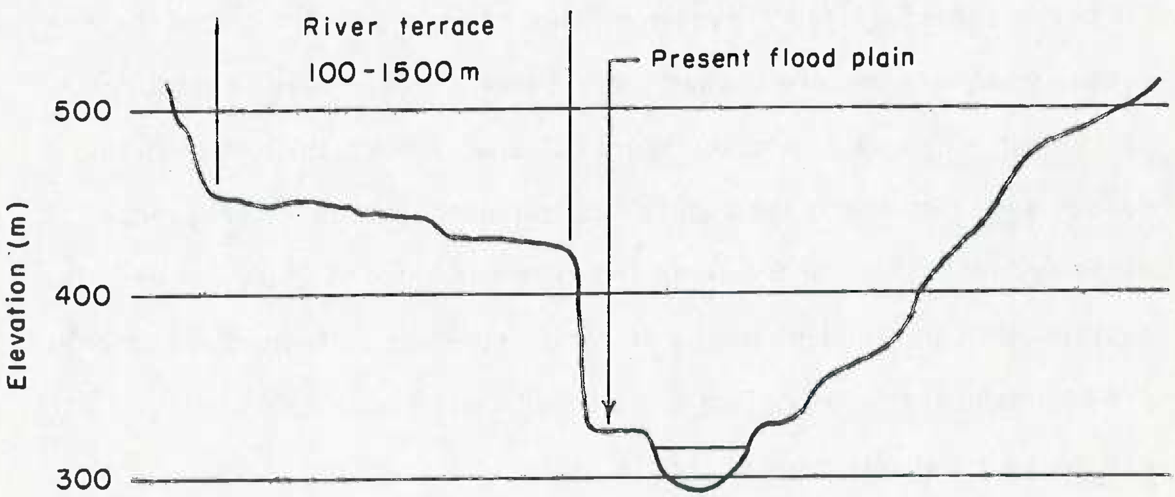

Figure 2.1 Cross Section of River Valley with River Terrace

Relative ease of accessibility to the sites was a concern in the selection since the research design called for frequent visits as well as the transportation to the site of research equipment. A final consideration was access to medical facilities, food, and adequate housing for the researchers and their families.

2.2.2 Site Selection

In May of 1981, a three-week reconnaissance was made through Nawal Parasi, Palpa, Gulmi, Baglung, and Parbat Districts of the Western Development Region along the Kali Gandaki and Bari Gad Rivers to identify farmer-managed irrigation systems. Since May is near the end of the dry season when streams are at their lowest flows, it was easy to identify systems in which water was too scarce to enable much cultivation in this season and those where the supply was abundant. In the water-scarce systems, little if any of the command area was being cropped, while in the systems with an abundant supply of water, rice was cultivated over most of the command area. Irrigation systems with an intermediate supply of water had maize growing in most of the fields.

While visiting an irrigation system, we discussed briefly with the farmers their cropping pattern and water supply situation. Four sites were identified for intensive study. Figure 2.2 shows the location of these four primary research sites as well as that of the ten additional sites where rapid appraisals were conducted. Thambesi, located on the south side of the Kali Gandaki River in northeastern Nawal Parasi District has an extremely scarce water supply. Most farmers were said to grow only one crop, monsoon-season rice, and the fields in the tail section of the system reportedly suffer from a shortage of water most years. The farmers said that in the winter the

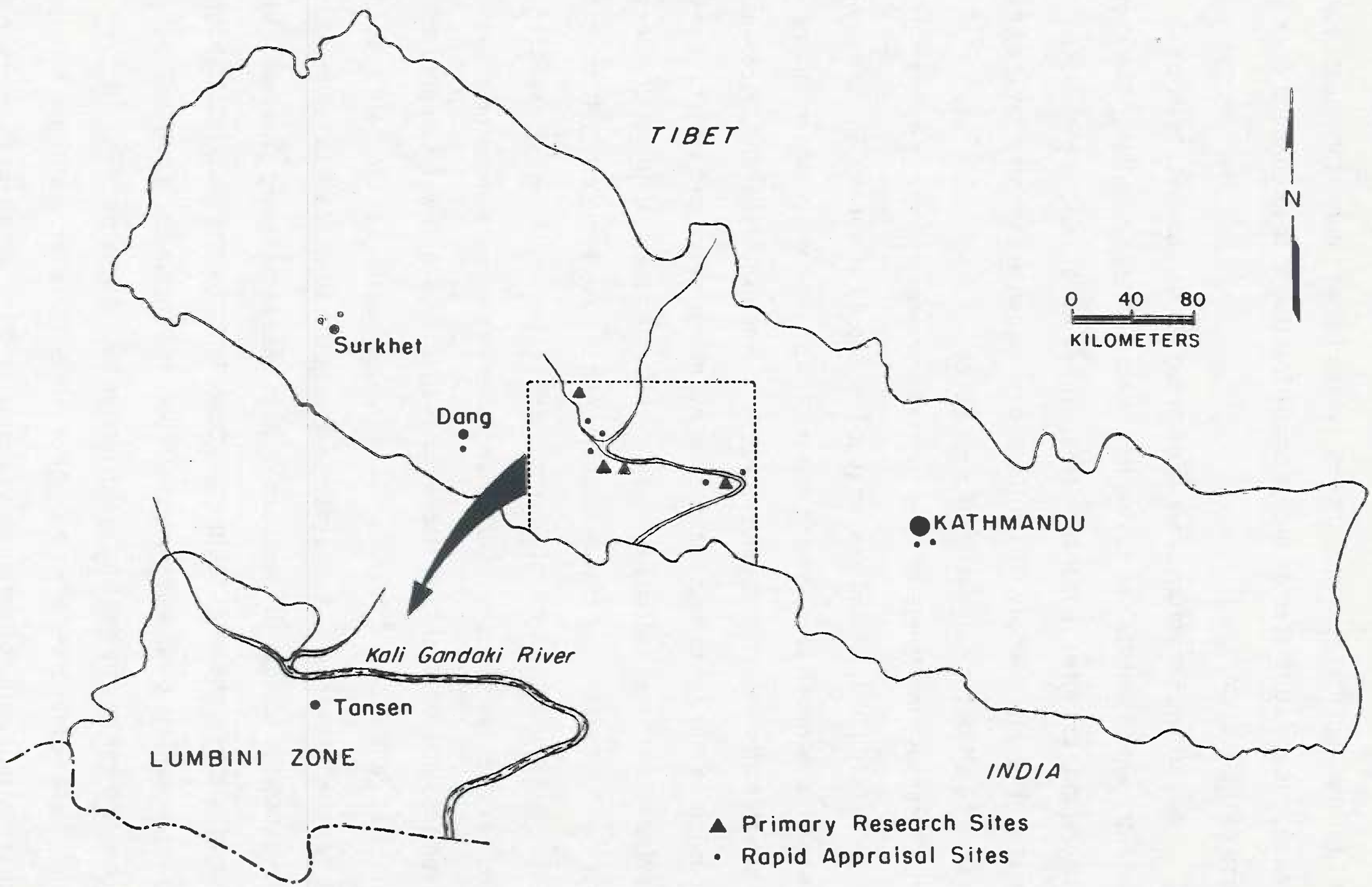

Figure 2.2 Location of Research Sites

supply is too limited to allow for cultivation of a wheat crop and the fields are left fallow. During the pre-monsoon season (when the reconnaissance was made), rice is cultivated on only a small fraction of the command area at the head of the system.

Argali and Chherlung, two sites along the Kali Gandaki in Palpa District, were identified as having intermediate water supplies. The cropping pattern in these sites is monsoon rice, winter wheat, and pre-monsoon maize. The water supply during the pre-monsoon season was said to be too scarce to allow for cultivation of a rice crop.

Majuwa, the fourth site, is located on the north side of the Bari Gad River in Gulmi District and has an abundant supply of water. The cropping pattern is monsoon rice, winter wheat, and pre-monsoon rice or maize. When this site was visited in May, 1981 (pre-monsoon season), rice was growing on more than half of the area and maize on the remainder. Farmers said that there was sufficient water to cultivate rice over the entire area during this season, but that they preferred to have some maize in their diet.

Because of its central location with respect to the other research sites and easy access to the town of Tansen where road transportation, food supplies, and medical facilities were available, Argali was selected as our place of residence and research base for the duration of the field research. It has the largest irrigation systems among the sites (both in terms of area irrigated and number of members). Both researchers had previously visited Argali and knew several residents. Chherlung is a one-and-a-half-hour walk from Argali; Majuwa, eight hours by foot; and Thambesi, a two-day trip, including one day by bus and ten to twelve hours walking.

These four sites then met all of our criteria for useful and efficient observation, data collection, and analysis. They were close enough to each other that visits would not require an inordinant amount of travel. Each site had at least two identifiable irrigation systems and organizations, and the size of command area and number of farmers in the organizations were thought to be representative of farmer-managed irrigation systems in the hills. The systems represented the desired spectrum of water supply conditions--scarce, intermediate, and abundant--and, consequently, different cropping patterns. They were all on river terraces.

After arriving in Kathmandu, Nepal, at the end of November 1981, another tour was made in December to confirm the site selection, observe what was in the fields at that time, and to inform people in Argali that we were planning to move there to live. The rest of December and January was spent in Kathmandu registering our affiliation with the Research Division of Tribhuvan University and the Research Centre for Applied Science and Technology, securing non-tourist visas and letters of introduction to the chief district officers of the districts in which we intended to conduct research, discussing our intended research with interested Nepali scholars and officials and international donor agency staff, securing air photos and maps (and permission to get maps from the district survey department offices) of the selected research sites, attending Nepali language classes, and purchasing equipment and supplies. On the first of February 1982, both families moved to Argali and resided there until mid-June 1983. Field data collection continued into September 1983.

2.3 Intensive Data Collection

2.3.1 Sample Selection

Each of the research sites included at least two irrigation systems: two in Thambesi, three in Chherlung, four in Argali, and four in Majuwa. The choice of the system in each site for intensive study was somewhat arbitrary. In Thambesi, the water-scarce site, the larger of the two systems was chosen. Two of the systems in Chherlung have long canals which were difficult to construct and required a great deal of effort to maintain. The larger and older of these two systems, referred to as the Thulo Kulo, was selected. In Majuwa, the system with the most abundant water supply relative to the area irrigated was selected to represent a situation where water shortage was definitely not a constraint to production.

Our intention in Argali was to do intensive research on the largest system, the Raj Kulo. However, in the spring of 1982, the Department of Irrigation, Hydrology, and Meteorology began a project to rehabilitate its main canal. At the time when water measurement devices had to be installed, it was unclear as to whether the work would be completed in time to allow for the planting of a monsoon rice crop. Also, it was not known what impact the rehabilitation would have on system performance. Since the objective was to study representative farmer-managed systems, we chose not to include fields and farmers from this system in our sample for intensive data collection. Instead, two of the smaller systems with somewhat different features, Saili Kulo and Kanchi Kulo, were chosen for study.

To analyze the performance of the irrigation systems, the sampling unit for data collection was the individual fields served by the system. A field was defined as an individual, separate parcel of land owned by one farmer. Many farmers owned more than one field within a system, and the size of the fields ranged from less than 0.05 hectares to more than 1 hectare.

In many irrigation systems, there is a significant difference in the amount of water and the reliability of the supply received by fields at the head of the system (where the main canal first enters the command area) and the fields at the tail. For this reason the sample fields were stratified according to location--head, middle, tail; or head and tail. At each of these locations within the command area, places on a secondary canal were selected where it was feasible to measure the flow of water supplied by the secondary to a cluster of fields below.

With the help of the farmers and the cadastral survey maps acquired from the district survey department offices, the boundaries of the separately owned fields in this cluster and their owners were determined. Depending on the number of fields below one of the flow-measuring devices, either all of the fields were included in the sample or a sub-sample of fields was randomly selected. Because of the slope of the land, the fields were terraced, and each field consisted of from 1 to 20 terraces depending on the size of the field and the amount of slope. In each field in the sample, one terrace was randomly selected for monitoring of the water status.

The farmers who owned and operated the fields which had been selected for the sample constituted the sample of farmers to be interviewed. The total number of farmers in the irrigation systems studied and the number in the sample at each site are listed in Table 2.1. Since the variance of the variables to be measured was not known, a statistical calculation of the minimum sample size could not be made. The sample size was chosen to be a sufficiently large percentage of the population to almost certainly be representative, yet small enough to make interviewing, crop cutting, and monitoring of fields manageable with the available staff.

Table 2.1 Sample Farmers

Site	Total Farmers	Sample Farmers
Thambesi, Tallo Kulo	55	25
Chherlung, Thulo Kulo	105	35
Argali, Saili and Kanchi Kulos	79	36
Majuwa, Damgha Kulo	111	32

2.3.2 Water and Soil Measurements

In three of the sites, intensive water measurement data were recorded to allow for the calculation of a partial water budget and the relative water supply. This was done for the irrigation systems as a whole as well as for subsections of the command areas. In Majuwa, the water-abundant site, there were no permanently installed instruments, but several spot measurements were made of the hydrologic data to provide some basis for comparison with the other sites.

Irrigation plus rainfall constitutes the water supply. Rain gauges were installed in each of the command areas and read twice a day--in the morning and evening. Depending on the volume of discharge and the slope of the canal, a V-notch weir, horizontal weir, or cut-throat flume was installed in the main canal to measure the total irrigation supply delivered to the command area. V-notch weirs were also installed in several secondary canals within the command area to measure the flow to selected subsets of fields. Readings were taken from the weirs and flumes in the morning and evening.

Water demand, consisting of evapotranspiration and seepage and percolation, is more difficult to measure. Evapotranspiration was approximated using class A evaporation pans, one of which was installed in each irrigation system. Measurements were taken in the morning and evening. The seepage and percolation portion of the water demand was estimated for rice by measuring the subsidence of the water surface in selected terraces. This could not be measured on an uninterrupted basis because of the continuous-flow method of water distribution and the extremely high infiltration rates. To take measurements it was necessary to be sure that a terrace was filled with water in the morning and then all inflow and outflow stopped for the day. Since within a field, irrigation went from terrace to terrace, i.e., there was not a separate intake from the field channel to each terrace, it was necessary to select the lowest terrace in a field for taking seepage and percolation measurements. If measurements had not been taken from the lowest terrace, supply to all of the terraces below the one being monitored would have been interrupted for the day. Farmers would not have permitted this. There was no reason to think that the lowest terrace would not be representative of the fields around it.

Using a sloping gauge (a ruler fixed at a 5:1 slope so that a small change in the vertical direction is magnified along the ruler), the change in the depth of water over a known period of time was measured. Rates of seepage and percolation were calculated for the sample terraces, and by extrapolation the seepage and percolation for subsections and the whole of the command area were estimated.[1]

The moisture status of the sample fields was monitored daily. When rice was in the field, note was made daily as to whether or not there was standing water in the field. This provided a commonly used count of stress

[1]For a more detailed and complete description of the hydrological measurements and estimation of seepage and percolation, see Yoder (1986) Chapter 5.

days in irrigated rice. Fields under rotational irrigation had to be checked twice a day because, due to the high infiltration rate, a field which received water in the evening would possibly have no standing water in the morning. A single daily observation would have overestimated the number of stress days.

For wheat and maize, gypsum blocks were installed in the fields for recording the moisture condition of the soil. Two blocks were installed--one at a depth of 5 cm and the other at 15 cm. The wire attached to the gypsum block had to be accessible for connecting the portable meter to take a reading and was, consequently, visible. Nearly half of the blocks were pulled out by curious persons before the problem was solved by running the wire just under the ground surface for 30 cm and then coiling the remainder of the wire and covering it with a small rock.

One local person, a high-school graduate, was trained in each site except Majuwa to take the water measurements. Data collection began in July 1982 with the transplanting of the monsoon rice and continued until June 1983.

A soil scientist from the Institute of Agricultural and Animal Science in Rampur was hired to assist with analysis of the soils. In each of the irrigation systems, he took numerous samples and dug several observation pits. He did particle and bulk density analysis and prepared soil maps of Thambesi, Chherlung, and Argali.

2.3.3 Farm Management Data

After spending several months in the field conducting informal interviews to gain some general understanding of the irrigation procedures and farming systems, questionnaires were designed for formal surveys.

Five persons were hired and trained as enumerators. They all had training and/or experience which expanded the disciplinary tools available as well as the relevant knowledge base. One had completed a master's degree in sociology, and two had recently graduated with bachelor's degrees in agriculture. The final two were local residents with B.A. degrees who had taught for one or two years in the local high school. These two had farmed land in the Argali irrigation systems and were particularly helpful in designing the questionnaires.

One general socioeconomic questionnaire was designed to elicit information concerning family composition, landholdings, cropping patterns on the different land types (irrigated lowland, irrigated upland, and unirrigated upland), off-farm employment and income, and livestock. This survey was conducted in two interviews of approximately one hour each. A short questionnaire on actual food consumption and preferences was also administered.

Separate questionnaires were formulated for each of the major crops grown. These included monsoon rice, winter wheat, and pre-monsoon maize and rice. Monsoon and pre-monsoon rice were grown only on lowland (<u>khet</u>) under flooded conditions. Wheat was grown on <u>khet</u> and irrigated <u>bari</u> (upland), and maize was grown on <u>khet</u> and irrigated <u>bari</u> as well as on unirrigated <u>bari</u>. Information was gathered from each sample farm on grain crop production on all the farm's land types. These surveys were used to acquire information about the cultural practices, use of inputs (labor, farmyard manure (FYM), fertilizer, pesticides), irrigation methods, varieties planted, estimate of total production of each crop, sales of production, etc. These were administered in two sittings--one after planting and weeding were completed and the second after the harvest and threshing.

Sample crop cuts were taken of rice, wheat, and maize grown on the khet; wheat and maize grown on irrigated bari; and maize grown on unirrigated bari. These were taken from all fields cultivated by the sample farmer--not only the sample field selected for the monitoring of the water status. Most farmers had at least two fields, while some had as many as seven or eight of one land type. In each field one sample of each different variety planted was cut. The farmers was asked the amount of FYM, fertilizer, and pesticide he had applied to the field. Planting and harvest dates and the farmer's estimate of the production from the field were also recorded. So that rates of input use could be estimated, the actual area of the field on which the relevant crop--rice, wheat, or maize--was grown had to be determined. The area of the field was known from the cadastral survey data from the Survey Department, but often a portion of the field was occupied by a house and/or barn, was left fallow, or was growing a different crop such as potatoes or vegetables. The area on which the grain crop was not being grown was measured and subtracted from the total area of the field. Areas were also corrected for the amount of the total area taken up by the bunds and canals.

If the field was one of the sample being monitored for water status, cuttings were taken from the particular terrace within that field which had been selected for observation. It it was not one of the sample fields being monitored, a terrace was randomly selected. Five square-meter samples of rice and wheat were cut and ten square-meter maize samples. For rice and wheat cuttings, a one-meter square frame was used and randomly placed at five different places in the terrace to cut a representative sample. A ten-square-meter rope frame was used for the maize cuttings, and the sample was taken from a point randomly selected on the center line running lengthwise through the terrace. After cutting, the samples were dried, threshed or shelled, weighed, tested for moisture content, and returned to the owners. The weight was corrected to a 14-percent moisture content for calculation of the yield. The crop cuts were taken either the day that the farmer was harvesting his field or a day or two earlier.

To get some idea of the size and ethnic composition of the total population, an all-household census of the wards in the area of the irrigation systems was attempted.[2] Each household was also asked whether it owned <u>khet</u> and/or <u>bari</u> or was landless.

2.3.4 <u>Participant Observation and Unstructured Interviews</u>

Living in one of the research sites and spending a considerable amount of time in the others allowed for participation in many of the work activities and many informal conversations with farmers and irrigation organization officers. We attended meetings of the irrigation organizations and observed them doing maintenance work on their systems. We participated in most of the crop production activities, even those which were mainly done by women. Our relative lack of skill was a source of amusement, but the desire to participate also created goodwill.

Through conversations, we learned much about the historical development, organization, and operation of the irrigation systems. Information that we were able to acquire about the dynamics of change in the agricultural and irrigation systems was primarily through informal conversations with individuals and groups of farmers.

---

[2]The ward is the lowest level political unit in Nepal. A village panchayat consists of nine wards, each of which has an elected ward committee.

2.3.5 Information on Irrigation Organizations

Contrary to expectations, a number of the irrigation organizations kept written records. All of the organizations in Argali and two in Chherlung had records of labor mobilized for maintenance, cash income and expense accounts, and lists of members and their water allocation. One organization in Argali had labor records for nearly every year going back more than 15 years. Some of the organizations also had minutes of meetings and written rules of operation. A careful examination of these records revealed them to be reasonable and internally consistent. Consequently, it was decided that they provided a rich source of detailed information--particularly for years preceding the present survey. The records were made available for hand copying by our enumerators.

For the irrigation systems in Chherlung and Argali, field-by-field water allocation figures were also recorded. Irrigation organization leaders and individual farmers furnished this information. This was done for these systems because the two locations had distinctly different water allocation principles.

Much of the information about the irrigation organizations was accumulated in conversations with the organizations' officers, groups of farmers and individual farmers. Nearly all of the member farmers could describe in detail how the organization was structured and operated and were proud to explain its functioning.

2.4 Extensive Data Collection

There were two purposes for the extensive data collection. The first was to expand the number of irrigation systems studied and the geographical scope of the research. Secondly, we wanted to develop, test, and refine a methodology for rapidly assessing existing irrigation systems, their potential for expansion, and the type of assistance required, if any. In this phase of the research, rapid appraisals of ten additional irrigation systems were conducted. Table 2.2 lists the districts in which this was done and number of systems investigated in each district.

Table 2.2 Rapid Appraisal Sites

District	Number of Sites
Gulmi	3
Surkhet	2
Kathmandu	2
Nawal Parasi	1
Tanahu	1
Dang	1

A question guide was designed to elicit information about the physical irrigation system, the irrigation management organization, agricultural practices, and the socioeconomic makeup of the area. This guide was used in interviews with irrigation organization officials and groups of farmers as well as for visual observation of the system. A group of four to six (the two principle researchers plus enumerators) would spend about two days in an irrigation system and conduct interviews in pairs. Irrigation organization officials were identified and interviewed. The researchers walked along the canal from intake to the command area making careful observations and field notes. Particular attention was given to the length of the main canal, the technology used, and technical problems. A portable V-weir was used to measure the discharge in the canal, and, frequently, the total discharge in the stream as a reference flow rate. The farmers were then asked to compare the minimum, regular, and maximum flows with this reference. Interviews were conducted with groups of farmers at each site. The farmers were asked to identify problems and to suggest means of solving them. Before leaving the area, the group of researchers discussed the findings and outlined a report. In this way, outstanding questions were identified and an attempt to find answers to them could be made before leaving the area. Discussing observations and solutions before leaving ensured that they were realistic and conformed with the feelings of the people actually using the system.

CHAPTER 3: THE RESEARCH SITES AND IRRIGATION ORGANIZATIONS

Before analyzing the organizations of the farmer-managed irrigation systems that were studied, it is necessary to describe (1) the setting and environment of the research sites and (2) how the organizations are structured and the ways in which the groups of farmers comprising the different organizations accomplish the various activities involved in managing an irrigation system. The hilly nature of the terrain and the lack of modern transportation and communication facilities results in many different microenvironments--physical and socioeconomic--in the hill region of Nepal. To understand the analysis of the farmer irrigation organizations, one must know something about the physical setting. An understanding of the agricultural system and the way in which irrigation fits into it is needed if one is to analyze irrigation management. First a brief description of the location of the research sites and of common elements among them will be given. The major part of the chapter will be devoted to a description of the four primary research sites--the setting, population, farming system, and irrigation organization (including management activities and organizational structure).

3.1 General Description of Primary Research Sites

3.1.1 Location and Physical Environment

The four primary research sites are sufficiently similar and near to each other that it is possible to make some general descriptive comments about them. All four sites are located in Lumbini Zone of the Western Development Region. Lumbini Zone shares a border with India on the south and extends north across the tarai into the southern part of the hill region.

The Mahabharat Range, characterized by steep slopes and peaks that reach as high as 3,000 meters, forms the hills and valleys of the hill region of the zone. The Kali Gandaki, one of the three major river systems which originate in Tibet to the north of Nepal and flow south through Nepal, makes a 90-degree turn to the east when it reaches Lumbini Zone and forms the northern border of the eastern half of the zone. Three of the research sites are located on river terraces along the Kali Gandaki--Thambesi in Nawal Parasi District and Chherlung and Argali in Palpa District. Majuwa, the fourth site, is located on a river terrace on the northern bank of the Bari Gad in Gulmi District. The Bari Gad is a major tributary of the Kali Gandaki draining the northern portion of Gulmi District. All the sites are in major river valleys at elevations much lower than the common image of Nepal as the home of the Himalayan mountain peaks. Elevations of the sites range from 300 meters at Thambesi to 700 meters at Majuwa. Figure 3.1 shows the location of the sites in Lumbini Zone.

The climate in all four sites is of a monsoon type with over 75 percent of the annual rainfall coming in the four months June through September. Table 3.1 presents the average monthly rainfall recorded at the two weather stations that are most representative of the sites. Chapkot is along the Kali Gandaki, approximately midway between Thambesi and Chherlung. Ridi Bazaar lies less than an hour's walk west of Argali. The rainfall measured in 1982-83 in Argali, Chherlung, and Thambesi is included for comparison.

The soils of the sites, while not identical, are sufficiently similar that the measurements of rates of seepage and percolation were nearly the same, certainly within the margin of error for such measurements.

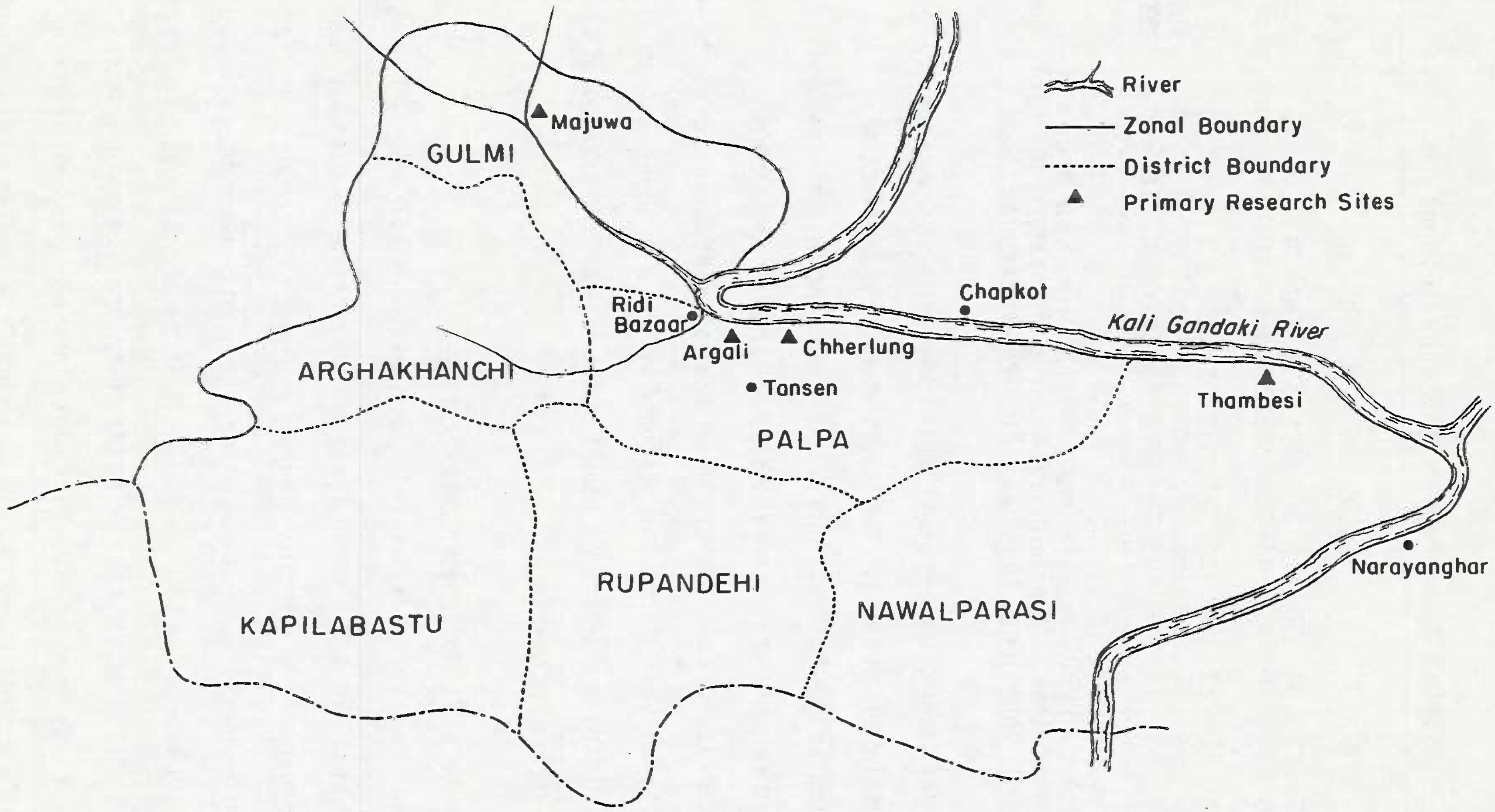

Figure 3.1 Location of Primary Research Sites in Lumbini Zone

Table 3.1 Average Monthly Rainfall (mm)

Month[1]	1	2	3	4	5	6	7	8	9	10	11	12	Total
Chapkot	27	22	34	56	128	303	475	353	240	79	7	10	1734
Ridi Bazaar	30	20	26	45	93	236	385	301	192	60	7	9	1404
Argali	24	2	28	26	158	75	343	260	260	3	1	1	1181
Chherlung	0	3	35	30	138	42	407	307	350	13	15	0	1340
Thambesi	17	3	15	18	138	294	576	480	191	0	18	3	1753

[1]Month No. 1 is January.
Sources: Chapkot and Ridi Bazaar: Dept. of Irrigation, Hydrology and Meteorology. Climatological Records of Nepal, 1966, 1977, 1982.
Argali, Chherlung, Thambesi: Field Measurements.

This brief description reveals that the four sites share generally similar physical environments. The feasible cropping systems are, therefore, similar in all sites. Data on sufficiency of subsistence food production and sales of grain reveal a high demand for agricultural production in all the sites. Farmers in all sites said they would grow three irrigated crops per year if they had adequate water. The observed variation in cropping patterns is primarily a result of the relative differences of water supply in the irrigation systems.

3.1.2 Agricultural Production Without Irrigation

Without irrigation, it is nearly impossible to grow rice in the monsoon season in the hills, as is evident in areas near the research sites which are exclusively dependent on rainfall. Piugha, a village that can be seen from both Argali and Chherlung, is such a place. Located between these two sites but on the north side of the Kali Gandaki, it is at the same elevation as Argali and Chherlung with identical rainfall and temperature. Being on a south-facing slope, it may be even better suited for intensive production--in terms of solar radiation--than these two villages which are located on slopes with a northern aspect. In Piugha, a maize crop is planted sometime between mid-March and mid-May. Planting is dependent on rainfall which is irregular and scarce in these months. A leguminous crop is intercropped with the maize. The maize is harvested in September and the legume in November. Farmers estimated the yield of maize to be two tons per hectare and that of the legume less than a ton.

Occasionally, if there is a good rain in late November or December, a small amount of wheat is planted in Piugha, but this had not been done in the previous five years. Rice, the preferred staple food, cannot be grown, and maize constitutes the major portion of the local diet. It was estimated that most households are not able to produce more than half of their food requirement, and most have family members working off their farm to earn income to purchase food. A majority of the households have family members working in India, many of them in the Indian army. Clearly, the absence of irrigation is a severe constraint to production in Piugha, and this affects the cropping, food consumption, and household employment patterns.

3.1.3 Irrigated Agricultural Production

All of the farmers who are members of the irrigation organizations in the primary research sites grow three crops a year if the irrigation supply is adequate. The monsoon season crop is rice, and in the winter, wheat is cultivated. Following the wheat harvest, either maize or rice is grown depending primarily, but not exclusively, on the amount of water available.

In Argali and Chherlung, almost no rice is grown in the pre-monsoon season because there is not enough water to allow everyone to grow it. The irrigation organizations in Chherlung have a rule giving priority of access to water for irrigation of maize, effectively prohibiting anyone from growing pre-monsoon rice. The amount of pre-monsoon rice grown in Argali is slowly increasing, and this could eventually lead to conflicts over water. Farmers in Majuwa grow both maize and rice in the pre-monsoon season, with the majority of the area producing rice. Because of its scarce supply of water, most of the irrigated land in Thambesi produces only one crop and is used as grazing land during the rest of the year.

3.2 Framework for Description and Analysis of Irrigation Organizations

The discussion of irrigation management activities will be organized according to the matrix that was presented in Figure 1.2. Rather than attempt to systematically document and explain the content of each cell for the irrigation systems in the four primary research sites, the description will be organized according to the twelve activities. However, not all will be addressed separately. As has been mentioned, drainage is not a concern. The systems are so old that little is known about the design process, and in many cases, no details of the original construction are known. Discussion of distribution and maintenance will describe the operation of the system. Where the interrelationships among the dimensions are especially important, these will be noted. For instance, construction and maintenance of the physical system will be described under the water use activity of acquisition.

The discussion of the research sites and irrigation organizations will begin with Argali since it was the researchers' place of residence and thus allowed for more detailed understanding of the structure of the organizations and the way in which they carried out management activities.

3.3 Argali

3.3.1 Physical Setting and People

Argali Village Panchayat occupies a large river terrace in the western part of Palpa District, a half-day walk west from Tansen, the district center.[1] It is bordered on the north and east by the Kali Gandaki and Kurung Khola rivers. To the south, hills rise up more than 700 meters above Argali. From Argali one can look down on Ridi Bazaar, less than an hour's walk to the west at the confluence of the Ridi Khola and Kali Gandaki rivers. Ridi Bazaar is one of the larger market towns in the interior of the hill region. Many Hindus, both Nepali and Indian, make pilgrimages to Ridi Bazaar to visit the famous Rishi Kesh temple. The trail through Argali is also the main route from Butwal--a market town on the _tarai_ which has historically served a large area to the north and west of Argali--through Tansen to Gulmi District, Dhorpatan, and Dolpa. Thousands of people, including heavily leaden porters, mule trains, soldiers on leave from the Indian army and British Gurkha regiments, pilgrims, and ordinary people, pass through Argali every year. Consequently, tea shops and hotels, where a night's lodging is included in the price of a meal, line the trail through Argali. Since 1981, tractors pulling trailors and four-wheel-drive vehicles loaded with goods and passangers have been passing through Argali in the dry season on a fair-weather road. This road, which is not maintained during the monsoon season, is closed by landslides after the first heavy rain. In Argali the

[1]Nepal is divided into several levels of political and administrative units. The village panchayat, which consists of nine wards, is the lowest level. There are over 3000 village panchayats in Nepal. These are aggregated into 75 district panchayats. The next higher level is that of the zone, of which there are 14. The national panchayat is the equivalent of a national parliament. Members of the village, district, and national panchayats are elected by the adult constituency which they represent. There is no zonal panchayat.

transport vehicles supply several small shops selling basic commodities such as cloth, kerosene, salt, sugar, and rice. There is also a local branch of the national agricultural cooperative (sajha) which supplies fertilizer and seed.

The irrigated land and the people of Argali are located within the jurisdiction of two village panchayats--Argali and Kheha. The researchers conducted an all-household census of seven of the wards in Argali and three wards in Kheha. These ten wards are the ones located in the immediate vicinity of the irrigation systems. A total of 454 households with an aggregate population of 2890 were surveyed. Brahmins dominate the area in every way and account for two-thirds (304) of the households. Magars are the second largest ethnic group with 78 (17 percent) of the households. The occupational castes (Kami, Damai, Sarki) account for 27 households and Chhetris 26. There are 11 Newar households and eight of various other ethnic groups or castes.

The river terrace which is irrigated by the four irrigation systems in Argali covers 325 hectares. Of the total area, 200 hectares are cropped and 150 hectares of this can be irrigated. In the winter and spring, this whole 150-hectare area is irrigated. However, only 88 hectares receive irrigation water during the monsoon season when rice is grown.

The four irrigation systems all have intakes on the Kurung Khola stream, a tributary of the Kali Gandaki. The Kurung Khola, while fluctuating greatly between the monsoon and dry seasons, has a base flow in the dry season of around 300 liters/sec. The four systems are termed the Raj Kulo, Maili Kulo, Saili Kulo, and Kanchi Kulo. In Nepali, the word "kulo" means canal. The Raj Kulo (Royal Canal) is so called because it is said to have been constructed by Mani Makunda Sen, the first Sen Rajah (king) of Palpa. Maili, Saili, and Kanchi mean second, third, and youngest daughter in Nepali. Table 3.2 presents some summary information concerning the four Argali irrigation organizations.

Table 3.2 The Argali Irrigation Organizations

System	Command Area	Khet (ha)	Total Farmers	Constraint to Expansion
Raj Kulo	102.9	46.5	158	Water
Maili Kulo	15.8	15.8	72	Land
Saili Kulo	14.9	14.9	51	Land
Kanchi Kulo	14.8	11.3	28	Water

The canals run parallel along the hillside as they approach the river terrace which they irrigate. Digging four parallel canals to deliver water from the same source to the same river terrace may seem inefficient, but there are reasons for and advantages in doing it this way. The traditional convention of water rights forbids the construction of a new diversion and canal within about 100 meters upstream of an existing one. After a system had been developed to irrigate a part of the Argali terrace, other farmers had to place their intake downstream from any existing diversions. An advantage of having multiple intakes and canals is that it enables the lower ones to capture water that passes through or under the upper diversons. On a steep, unstable hillside, several smaller canals are less destablizing than one large one. When there are parallel canals, there are opportunities to share water between systems when one experiences problems delivering water. Command areas of the systems are located as is shown in Figure 3.2.

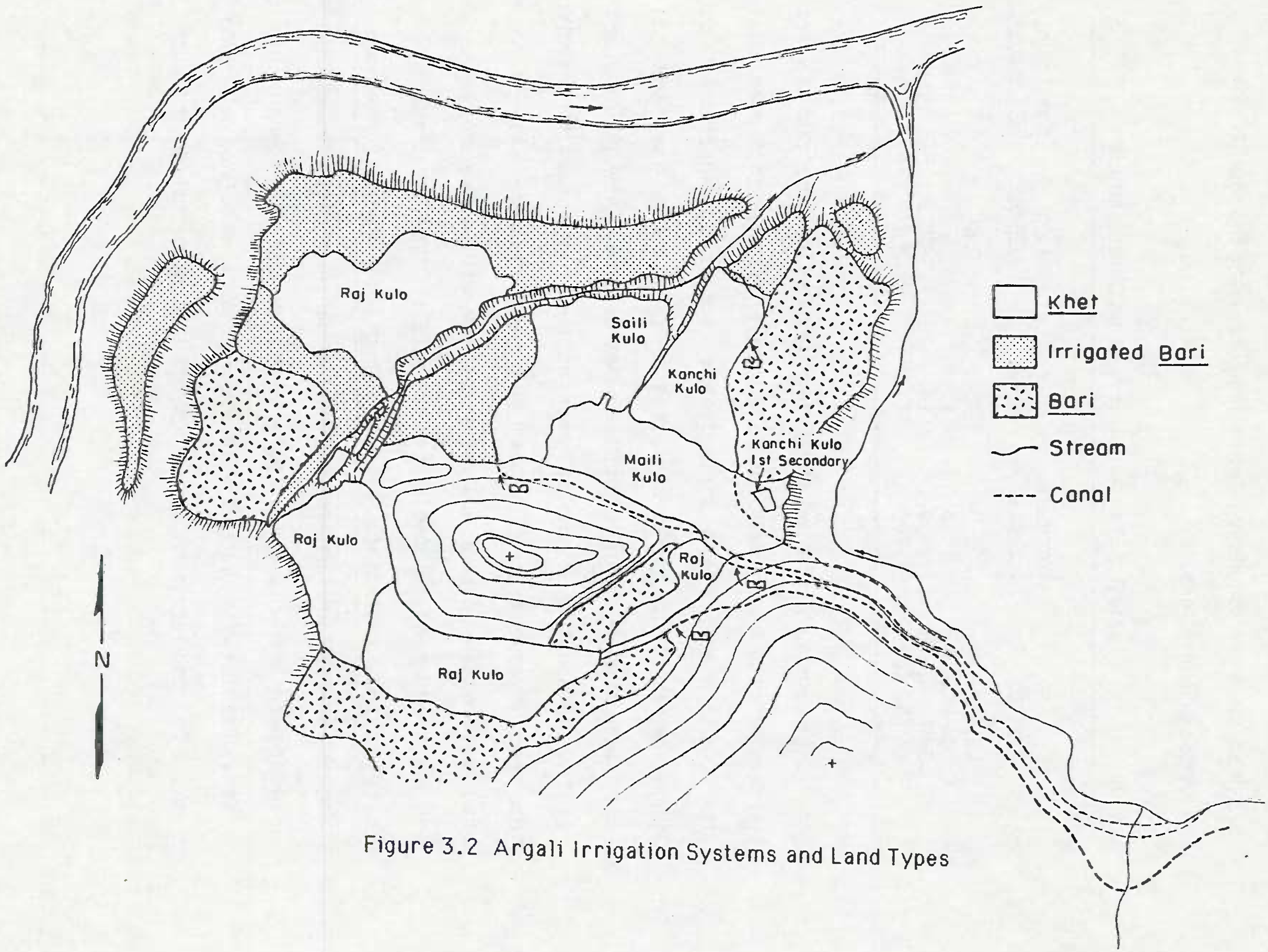

Figure 3.2 Argali Irrigation Systems and Land Types

3.3.2 Farming System

Cropping Pattern on Khet. The most important crop in the farming system is monsoon rice which can only be grown on the khet fields. (The term khet refers to fields which have been terraced, leveled and bunded for the cultivation of rice by flood irrigation.) Farmers establish seedbeds in June while maize is in the fields. In 1982, the mean date for planting seedbeds was June 19, and all were established within a two-week period. Seedlings were transplanted between July 16 and August 9. The mean date of transplanting was July 27, and the standard deviation was only five days. Each of the 36 sample farmers who were interviewed about cropping practices planted Chherlungi Yellow, a traditional variety of rice. It was said to produce more than other varieties and to yield a higher proportion of edible grain when husked and polished. Harvesting took place between November 12 and 21 with a mean harvest date of November 17 and standard deviation of only three days. From transplanting until harvest, the rice crop was in the field an average of 113 days. The average yield of 89 sample crop cuts was 3.3 tons/ha. Nearly all rice is retained for home consumption; only three of the sample households reported sales of rice.

The farmers in Argali used more commercial fertilizer on rice than those in the other sites. Only three farmers in the sample used no complex (NPK, 20-20-0) nor urea. Twelve farmers used both a basal application of complex and a top dressing of urea, while five applied only complex, and 16, only urea. Application rates were low--42 kg/ha of nitrogen and 9 kg/ha of phosphorus.[2] Farmyard manure (FYM) was generally not applied to the rice

---

[2]The calculation of these averages did not include farmers who did not apply the concerned fertilizer.

crop. A common practice in all sites to improve fertility is to apply chopped up leaves when sowing the seedbeds. The most common type of leaves used comes from a bush termed asuro by the farmers. The botanical name of this plant is adhutoda vasica.

Winter wheat was sown on the khet fields between November 18 and December 19. RR21 was the variety that everyone grew. Harvest was between the 5th and 26th of April. The mean harvest date was April 18 and the standard deviation only five days. On the average the wheat crop was in the fields for 132 days. The average yield of 83 sample crop cuts was 2.5 tons/ha. Wheat is the cash crop in the farming system, and all but nine of the farmers reported sales of wheat. Each year people from food-deficit areas north and west of Argali come to the farmers' houses shortly after the harvest. In 1982, within a span of about a month, there was almost no wheat for sale locally, and what was available had risen in price from Rs. 2.35 per kg to over Rs. 4.

There are usually 2 to 3 applications of irrigation water for wheat after it has been planted. Most farmers in all sites apply commercial fertilizer to the wheat crop as well as FYM. Among the farmers surveyed in Argali, average application rates of those using fertilizer were 68 kg/ha of nitrogen and 17 kg/ha of phosphorus. The wheat is not weeded because at the appropriate time the plants are said to be too weak and would be damaged by persons doing the weeding. Another reason given for not weeding is that the mature weeds are desirable for animal fodder, and in the latter part of the season these are harvested daily.

Maize was planted on the khet between March 4 and May 19. Fields planted in March had been left fallow during the winter wheat season, and a longer-season variety of maize was planted on them. The mean planting date was April 16. The most common variety was Bergelli White, a local variety, followed by Rampur Yellow, an improved variety. The most oft-mentioned reason for selecting a particular variety was that it would ripen on time, reflecting the need to harvest the maize in time to plant the monsoon rice crop. All of the sample farmers intercropped a legume with the maize as a green manure. The mean harvest date for the maize crop was July 20 and the standard deviation less than six days. The average yield of 92 sample crop cuts was 1.7 tons/ha. On the average, the maize crop was in the field less than 95 days, reducing the yield somewhat.[3] It did not have an opportunity to ripen to maturity as was evidenced by the very high moisture content registered when the crop cuts were taken.

More than half of the farmers applied commercial fertilizer to the maize, and nearly all used FYM. Application rates were 50 kg/ha of nitrogen and 5 kg/ha of phosphorus. Farmers weed the maize once, and when they do, they dig up the soil vigorously, disturbing the roots and leaving the young plants lying over. It would appear that such violent treatment might reduce yields. Late in the season, the lower leaves are stripped from the stalks and used for fodder.

There is sufficient water in the system during the maize season to irrigate the crop several times. Farmers, however, prefer to wait for possible rain even when the maize is suffering moisture stress. Maize matures during a time when pre-monsoon storms accompanied by high winds are not uncommon. If the soil is wet from an application of water when a storm arrives, the crop will almost certainly lodge. Farmers are willing to

[3]There was a strong negative correlation between the date of planting and maize yield, i.e., the later it was planted the lower the yield. Since it was all harvested at approximately the same time, it appears the yield suffered from not being allowed to mature in the field.

accept yield reductions due to stress rather than the losses from having the maize lodge. The crop is much more likely to survive a windstorm without lodging if the soil is dry. Research is needed to determine why the maize has such a poor root structure that it is highly vulnerable to lodging in wind.

This three-crop pattern, with a crop in the field 340 days of the year, requires quick turnaround time between harvest of one crop and sowing of the following one. Farmers have developed practices which minimize the turnaround time between wheat and maize and between maize and rice. While the wheat crop is still in the field, the FYM that will be applied when the maize is planted is carried from the barn and deposited in piles in the field. Less than a week before the wheat is harvested, water is applied to the field so that the soil will be at the proper moisture content for plowing and maize planting immediately following harvest. It is not uncommon for the wheat to be harvested from a field in the morning and maize planted in the afternoon, and there is rarely a gap of more than a few days.

A similar practice is followed for maize harvest and rice transplanting. Farmers need to transplant the rice by late July to ensure an adequate water supply for the rice, but they want to leave the maize in the field as long as possible so as not to reduce the production too much. On the day of land preparation, the field is flooded in the morning, often while maize is still standing. Maize stalks are cut and piled on the bund. While the bunds are being repaired and the field plowed, the maize stalks are carried to the house. Within a few hours the first terrace is ready and transplanting begins. Through the use of exchange and hired labor, most individual fields can be harvested of maize and transplanted in rice in one day. Depending on the amount of land a farmer has, he might be able to do his entire farm in one day.

A quick turnaround is not deemed to be important between the monsoon rice and winter wheat crops because of the farmers' experience that the wheat will ripen at approximately the same time whether it is planted immediately after rice harvest or several weeks later. In this three-crop pattern, it appears that the maize crop is the one that suffers because of the need to harvest it before it is fully mature in order to transplant the monsoon rice. Farmers are well aware of this and are very much interested in getting seed for a shorter-season variety. Table 3.3 presents a summary of the crop cut data for crop production on the khet fields in Argali.

Table 3.3 Sample Crop Cuts, Argali Khet

	Rice	Wheat	Maize
Number cuttings	89	83	92
Planting Date[a] - mean	27/7	7/12	16/4
Harvest Date[a] - mean	17/11	18/4	20/7
Yield[b] - mean	3.3	2.5	1.7
minimum	0.6	0.6	0.6
maximum	4.9	4.0	5.4
s.d.[c]	0.6	0.8	0.9

[a](day/month) [b]tons/ha [c]standard deviation

Annual grain production per hectare was thus estimated to average 7.5 tons--3.3 tons of rice, 2.5 tons of wheat, and 1.7 tons of maize. This compares very favorably with the Agricultural Department's target of 7 tons/ha/year.[4]

Cropping Pattern on Irrigated Bari. The most common cropping pattern on irrigated bari (upland fields which are not leveled and bunded) in Argali is winter wheat followed by summer maize. All of the sample farmers with

[4]This was the goal of the agriculture department's Cropping Systems Project which was supported by USAID with technical assistance provided by IADS.

irrigated bari grew these crops. A third of them also planted a crop of mustard between maize harvest and wheat planting. Most farmers with irrigated bari reserved a part of it for vegetables and potatoes.

Wheat was planted on the irrigated bari between November 30 and December 26 with December 15 the mean planting date. Harvest took place from April 20 to 30. The mean harvest date was April 24, and on the average, wheat was in the irrigated bari fields 130 days. The average yield rate of 23 sample crop cuts was 2.9 tons/ha. All farmers applied commercial fertilizer, and nearly all used FYM. The wheat was irrigated two or three times after planting.

Maize was planted on the irrigated bari between May 3 and 24. May 12 was the mean planting date. Every sample farmer planted Rampur Yellow, a variety developed at the Maize Research Centre in Rampur. The two reasons given for planting this variety were that it is high-yielding and that it does not lodge easily. Harvest of the maize on irrigated bari took place between August 26 and September 16 with a mean harvest date of September 4. This means the maize on irrigated bari was in the field an average of 115 days, or more than 20 days longer than the maize grown on khet. Yields of 17 sample crop cuts averaged 3.9 tons/ha which is significantly greater than the 1.7 tons average of the khet maize.

Only three farmers did not use commercial fertilizer on this crop--most applied only a top dressing of urea, while several also used a basal application of complex (20-20-0). Irrigation was limited to one time prior to planting. Most farmers planted a legume as an intercrop which was allowed to mature and was used for human consumption. The average measured grain production on the irrigated bari was 6.8 tons/ha--2.9 tons of wheat and 3.9 tons of maize.

This is not much less than the 7.5 tons of grain produced on the khet fields. When one considers that the yield of edible rice after milling is only half that of the harvested yield (half of 3.3 is 1.65), the irrigated bari yielded more in terms of edible grain per hectare than did the khet (5.85 for the khet versus 6.8 for irrigated bari). Since the caloric content of wheat, maize, and polished rice are nearly the same, the irrigated bari yielded more calories per hectare than the khet. But rice is the preferred grain, and all farmers will grow it if possible.

Cropping Pattern on Unirrigated Bari. On the unirrigated bari in Argali, two distinct cropping patterns, primarily determined by the location of the fields, were observed. The farmers who are members of the Kanchi Kulo organization have bari fields nearby which are too high to be irrigated by the Kanchi Kulo canal. Nearly all of these farmers grow only a maize crop on these fields. Several follow the maize with a mustard crop. Some of the members of the Saili Kulo organization live in Kheha Panchayat high on the hill overlooking Argali from the south. They too grow maize in the spring-summer, but most follow it with a winter crop of wheat or barley. Although it was not monitored, there is probably more rainfall in the winter at that higher elevation of over 1200 meters.

Maize on the unirrigated bari was sown between April 15 and May 17, with May 10 the mean planting date. The mean harvest date was September 9, harvest taking place between August 28 and September 19. The average yield of 33 sample crop cuts was 4.4 tons/ha.[5] All but one farmer applied FYM, but fewer than half used commercial fertilizer.

---

[5]The one irrigation that was applied to the maize prior to sowing on the irrigated bari did not seem to make a difference in 1982 since yields from the unirrigated bari exceeded those of the irrigated bari. Likely there are years when there is not enough rainfall in May to make it possible to plant a maize crop, and then that one irrigation would be significant.

The rainfed wheat and barley grown in Kheha Panchayat yielded poorly. The average of 16 crop cuts was only 1.6 tons/ha. Farmers applied no FYM or commercial fertilizer to this crop. The average planting date was October 1 and harvest date March 21. The crop was, on the average, in the field 171 days. Table 3.4 summarizes the data for crop cuts taken from irrigated and unirrigated bari on the Argali river terrace.

Table 3.4 Sample Crop Cuts, Argali Bari (Irrigated and Unirrigated)

	Irrigated		Unirrigated
	Wheat	Maize	Maize
Number cuttings	23	17	33
Planting date[a] - mean	15/12	12/5	10/5
Harvest date[a] - mean	24/4	4/9	9/9
Yield[b] - mean	2.9	3.9	4.4
minimum	1.3	1.7	2.8
maximum	5.4	6.0	6.4
s.d.[c]	1.1	1.0	0.9

[a](day/month) [b]tons/ha [c]standard deviation

Livestock. Livestock are a crucial component of the farming system in the hills of Nepal. Water buffalo are kept primarily as a source of FYM and milk. Most of the dairy products—milk, yogurt, and ghee (clarified butter) are consumed at home. A third of the households reported selling some. Only two of the 36 sample households did not own female water buffalo, and the number owned ranged from 1 to 7. Two-thirds of the sample households kept bullocks, the only source of traction in the farming system. Fewer households raised goats (mainly to sell), cows (to breed bullocks), and chickens.

Because of the intensive use of the land for crop production, the animals are primarily stall-fed. The bullocks and goats are sometimes taken out to graze away from the fields. Farmers know which trees provide good fodder and how frequently the leaves can be harvested from the different species. Cutting fodder to feed the animals is both a time-consuming and dangerous task. On one day in 1982, two young women fell to their deaths while cutting grass on the steep slopes overlooking Argali. Staff of the hospital in Tansen reported that broken bones resulting from people falling from trees while cutting leaves for animals number among the most frequent injuries treated.

Crop production in the farming system is extremely intensive, and it is the well-managed irrigation systems that are the life-blood of the farming system and the community. The farmers' ability to organize to manage the water resource is primarily responsible for the level of agricultural production achieved in Argali.

3.3.3 Irrigation Management Activities

Of the four irrigation systems in Argali, the Raj Kulo is the largest and has the highest degree of organizational structure. The other three systems are organized in a manner very similar to that of the Raj Kulo organization, and the description of Argali irrigation organizations will, therefore, focus on the Raj Kulo system.

Water Acquisition – Construction. The Raj Kulo irrigation system is very old. If the oral tradition, known by nearly everyone in Argali, is true, the Raj Kulo system is more than 400 years old. According to this tradition, Mani Makunda Sen, the first Sen Rajah (king) of Palpa, was responsible for the construction of the Raj Kulo system, and, hence, the name Raj Kulo or Royal Canal.

Mani Makunda Sen, who ruled in the first half of the 16th century, is also said to have established the famous Rishi Kesh temple at Ridi Bazaar. A source of income was needed to support the operation of the temple, and a common means of providing for such income was to grant land to the temple. A land grant of this type is termed guthi. Tenants who farm the land must deliver a portion of their produce to the temple. The guthi for the Rishi Kesh temple is said to have first been established near the temple along the Kali Gandaki river, but a flood washed away the land. A new location for the guthi had to be found, and land located in Argali was selected. The Raj Kulo is said to have been constructed by Mani Makunda Sen to irrigate this land in the tail end of the present command area of the Raj Kulo. Part of the production from this land still goes to the Rishi Kesh temple, and until recently all the water would be taken to this guthi land first for rice transplanting.

While it is not possible to establish for certain that the canal was built more than 400 years ago by Mani Makunda Sen, historical evidence was found that the Raj Kulo was in existence before 1787. An official royal document dated 1787 was in the possession of one the members of the Raj Kulo organization. This document upheld a land grant of khet in the Raj Kulo command area to a man named Narapati. It mentions the Maili Kulo canal as one of the boundaries of the land grant indicating that it, also, was built at least 200, if not more, years ago. This certificate was issued by Man Mahadatta Sen, one of the descendants of Mani Makunda Sen and was confirmed by Rajendra Shah in 1820 after Palpa became part of the nation of Nepal ruled by the Shah dynasty. Sufficient evidence has not yet been found to establish whether the oral tradition is correct or not, but there is certainly evidence that the system was constructed at least 200 years ago and probably more.

The system has been greatly improved since its original construction, and much of the improvement has taken place in the past 25 years. Prior to the land reform acts of 1957 and 1964, much of the land was owned by several families and farmed by tenants. These tenants were responsible for the operation of the irrigation system and were subject to fines for stealing water or being absent from work. At the end of the year the fine money was spent for a large feast for the organization. The tenants were not interested in using this money to improve the system since they were not secure in their tenancy and, thus, could not be sure they would benefit from any improvements. Now most of the land is farmed by owner-operators, and the custom of spending the annual fine money on a feast has been abolished. These funds have been, over the years, invested to improve the canal. It has been enlarged, and some areas subject to landslides have been put underground in tunnels dug on contract by agris.[6] In the spring of 1982, the Department of Irrigation, Hydrology, and Meteorology (DIHM) invested approximately Rs. 450,000 to improve the canal by lining parts of it and putting sections undercover in cement pipe. The impetus for this improvement was damage done to the canal when a road was being constructed above it, causing rock and dirt to fall down the hill into the canal.

Water Acquisition - Maintenance. Because of environmental conditions, the irrigation systems in the hills of Nepal require considerable

---

[6]The term agri refers to people of different caste and ethnic groups who have specialized skills in tunnel- and canal-digging. These skills were developed in the now defunct mining industry. The records of the Raj Kulo organization included a copy of a contract with two agris from the village of Pamphu in Gulmi District for the construction of a length of tunnel.

ongoing seasonal and annual maintenance. The heavy rains of the monsoon are the chief cause of damage to the diversion and conveyance structures. After a monsoon storm, the streams supplying the systems are transformed into raging torrents which often destroy a system's diversion structure. These streams carry a high silt load which is deposited in the canal. The steep hillsides along which canals run are unstable, and when the soil is water-soaked after a hard rain, landslides may block the canal or sweep it away altogether.

The Raj Kulo organization, as well as the other irrigation organizations in Argali, executes several types of maintenance activities. Every year in late May and June, shortly before rice transplanting, routine maintenance of the intake and canal is conducted. This involves removing silt from the canal, plugging leaks and reinforcing the canal walls, and repairing the diversion structure with stone and mud. After the rice has been planted, it is necessary to make almost daily minor repairs and to have a system of early warning in the event that the canal is damaged by a landslide or flood. Two men patrol the canal each day. It is their duty to make minor repairs. If more work is required than these two can accomplish, one is to go back and report to the chairman (mukhiya) of the organization. The mukhiya will assign the required number of men to complete the task. This type of maintenance is referred to as jhikuwa.

In the case of a situation requiring much labor, the mukhiya will declare an emergency, and all members of the organization are expected to go to work until the system is repaired. At times, emergency maintenance work will continue at night by the light of lanterns and torches. The farmers work hard to minimize the duration that the supply is shut off, because if the supply is interrupted for too long, the fields dry and crack and it will no longer be possible to distribute water by continuous flow to the whole system. As the farmers know and as the data collected on infiltration show, after the soil has cracked the rate of seepage and percolation increases dramatically.[7] Emergency maintenance is referred to as jhara.

The maintenance needs during the dry season are much less than those of the monsoon season. There are no landslides to damage the canal. Floods are very infrequent, and the diversion structure requires little repair. Small leaks gradually appear in the diversion and canal walls. Crabs digging through the walls are a primary cause of leaks. If the flow in the system is not sufficient when farmers want to irrigate their wheat or maize, they will make the needed repairs.

The organization as a whole is responsible for maintenance of the intake and main canal. Only the farmers receiving water from a specific secondary and/or tertiary channel are responsible for maintaining these lower levels of the system.

Water Allocation. Water in the Raj Kulo system, as well as the other three in Argali, is allocated in proportion to the area irrigated during the monsoon rice season. The fields that are entitled to water are designated, and each is entitled to a fraction of the flow in the system equal to the fraction of the total irrigated area for which it accounts. For example, a field that is equal to two percent of the irrigated area is entitled to two percent of the flow in the system during the monsoon season. Each field has been assigned an allocation of "so many muri of water." This derives from the time, said to have been in 1868, when the land was measured and registered for taxation. The unit of measure of area was the maato muri,

[7]See Yoder (1986), Chapter 5, for a detailed analysis of seepage and percolation rates.

and each plot's water allocation was recorded as the number of maato muri of its area.[8] With the help of the farmers and the cadastral survey maps, it was determined that approximately 46.5 hectares of khet have an allocation for water from the Raj Kulo system during the monsoon season.

In the winter wheat season, the water is allocated more widely. Even though the volume of flow in the system is considerably less in the winter than during the monsoon, wheat requires so much less water that the area that is irrigated is expanded to over 102 hectares. Farmers with bari fields that lie in the command area of the Raj Kulo system but do not have an allocation of water for the monsoon season are permitted to irrigate their wheat crop in these fields. They are required to work on the canal the day before they want water. If there is a shortage of water, or if a member of the organization wants to irrigate his khet field at the same time that a person wants to irrigate bari, the khet field has a higher priority. All bari fields are of equal priority, whether owned by a member or nonmember, and the priority for irrigating is established by the order in which farmers wanting to irrigate arrive at the main canal. Nonmembers are also allowed to use water from the system in the same way at the beginning of the pre-monsoon season to irrigate maize on their bari. As soon as rice seedbeds

[8]There is considerable uncertainty as to the exact area represented by a maato muri. Maato means soil, and muri is a volume measure (approximately 90 liters) used for rice and other grains. Many people were questioned about the origins of muri as a unit for measuring both land and water. Most farmers thought maato muri had originally referred to the land area required to produce one muri of rice. According to Regmi (1978), the area represented by a maato muri was standardized at 1,369 square feet in 1907. When the water allocation was first formalized, the term muri was used as the share of water allocated to one maato muri of land. The term muri in an irrigation system is an accounting unit much like the tenah in the Balinese subaks (Geertz 1980). It can refer to land area, a share in the water rights of the system, or a volume of grain.

are established on the khet, however, the water allocation rule reverts to that of the monsoon season, and bari fields can no longer be irrigated.

The water allocation principle, thus, changes with the season and, therefore, with the level of supply relative to the demand and the importance of the crop. Rice is the preferred food grain and requires the most water. The allocation of water during the monsoon rice season is, therefore, more carefully defined and restricted than during the other seasons.

Water Distribution. An irrigation organization which allocates water in more or less definable units must have a method of measuring out the supply so that farmers' fields receive the proportion of the supply to which they are entitled. In Argali during the monsoon rice season, this measured distribution is accomplished by using a device called a saacho. A saacho[9] is a horizontal proportioning weir fashioned from a log with two or more notches of equal depth and varying length cut into its top. It is placed in the canal perpendicular to the flow so that all of the water is forced to flow through the notches and is divided in the same proportions as the ratio of the lengths of the notches. In the Raj Kulo system, they are used to apportion water from the main into secondary canals, from secondaries into field channels, and from field channels into individual fields. At each such division point, the ratio of the water allocation of the land supplied by the channel taking off from each of the notches is the same as the ratio of the lengths of the notches.

The saachos are used only for distribution of water by continuous flow. If the supply should drop to a level such that it is not possible to distribute it

---

[9]These same devices are found in many of the irrigation systems that were studied in Nepal as well as in a number of other Asian countries. In Indonesia they are referred to as penaro (Coward, 1985b), in Sri Lanka, karahankota (Leach, 1961), and in Thailand, tae wai or mai wai (Tan-kim-yong, 1983).

continuously to all fields, the <u>saachos</u> are removed and rotational distribution is practiced. They are, thus, used for distribution only during the monsoon season and are either removed from the channel for the rest of the year or a hole is dug to allow the water to flow under the <u>saacho</u>. After the rice transplanting has been completed, the <u>saachos</u> are all put back into place, and all farmers receiving water below a <u>saacho</u> are supposed to supervise the placing of it. They can check it at that time to make sure that the notches are the correct size and that the <u>saacho</u> is fixed in a level position. Any person absent has no right to complain about the size and placement of the <u>saacho</u>. The picture in Appendix 1 shows a group of farmers overseeing the installation of a <u>saacho</u>.

Distribution of water during the winter wheat and pre-monsoon maize seasons is by rotation from field to field in no designated order. The farmers wanting to irrigate wheat on a particular day meet at the main canal in the morning and decide among themselves the order in which their fields will receive water. One farmer irrigates his field until it is adequately covered, and then the next farmer in order diverts the water into his field.

<u>Resource Mobilization</u>. The mobilization of resources to maintain the diversion structure and main canal is the most critical activity in many of Nepal's hill irrigation systems including the Raj Kulo and the other three systems in Argali. Without an effective means of mobilizing resources, particularly labor, for the major annual maintenance prior to the monsoon

and nearly continuously throughout the monsoon season, the system would soon fall into complete disrepair.[10]

For the most part, resources are mobilized from the members of the organization in proportion to the benefits they receive from the system, i.e., in proportion to their water allocation. When the Raj Kulo organization conducts routine maintenance, members are required to provide one laborer for every 40 maato muri of water allocation. Thus, a household with an allocation of 40 maato muri must provide one laborer each day of ordinary maintenance work, while one with an allocation of only 20 maato muri must provide one laborer on alternate work days. This results in a total of approximately 50 laborers per day. If cash is raised to purchase cement or to pay agris to dig a tunnel, this is also done in proportion to each member's water allocation.

This principle of proportionality of costs assessed to benefits received is not followed in times of emergency. When there is an emergency situation requiring a large amount of labor to restore the system quickly to effective operation, each member household is required to supply one laborer irrespective of the amount of its water allocation. In 1983 at a meeting of the organization, some members with small water allocations protested the unfairness of requiring each household to provide the same amount of labor in times of emergency. They argued that the proportionality rule should be employed then as well. After a great deal of discussion, the decision was

---

[10]Immediately prior to the annual routine maintenance in June, a system may appear to be in "complete disrepair." However, in several weeks or even less, the organization can completely transform the appearance of the system as water becomes more important. This seasonality in the need for water and the appearance of the system must be remembered when judging the effectiveness of irrigation organizations.

reached to retain the rule and to be careful that an emergency was declared only when there was truly an emergency.

Maintenance of the Raj Kulo system for water acquisition consumes a substantial amount of resources every year. Eighteen years of the organization's attendance records were available for analysis and are presented in Appendix 2. During these years the average annual number of man-days of routine maintenance was 1,165 and of emergency maintenance, 544 man-days. In addition, for a period of three months during the monsoon, two men patrol the canal every day. There is some additional maintenance during the winter and spring when needed to increase the supply to irrigate wheat and maize. This, however, is not recorded in the attendence book kept by the organization's secretary. This work is done only by the farmers who want to irrigate on a particular day and involves only minor repairs to leaks in the intake and canal.

Women and low caste members of the organization are not permitted to participate in the maintenance work. The reasons for this prohibition relate primarily to Hindu concepts of purity and pollution. Since rice from the guthi land is given to the Rishi Kesh temple in Ridi, there is the concern that women in menses and untouchables, by doing maintenance work on the canal, would defile the system and the rice. In lieu of maintenance work, the lone untouchable member of the Raj Kulo organization has traditionally provided a female goat for an annual sacrifice to the Goddess Madhumati. Currently, since the price of a goat has increased substantially, he pays the fine for being "absent" from maintenance work.[11] Households with no living male 15 or older are excused from providing maintenance labor. However, if there is a male family member of at least 15 years of age who is living and working in some other location, the household is responsible to provide labor and must pay the normal fine for being absent from work or hire a man to work on the system for the household.

The fine rate set in 1981 and followed in 1982 was Rs. 6 for being absent from routine maintenance work. This was a little less than the daily wage rate in the area. Since in times of emergency, it is critical to repair the system quickly and the work involved might be more dangerous than ordinary maintenance, the fine rate was set higher at Rs. 8. Fines that are levied can be collected because, as one farmer in Argali said, "If the fine is not paid, the organization can deny the offender water." At a meeting of the Raj Kulo organization held in December 1981, a decision was made to appoint two members to collect the fines from the previous monsoon season and any that were outstanding from previous years. They were to keep six percent of the collected money as remuneration and turn the remainder over to the organization's secretary. Fine money that is collected is now saved to invest in improvements in the system. Until it is to be spent, the money may be loaned to members who pay interest to the organization.

It was reported that in the late 1950s the fines were not collected for several years and accumulated to significant amounts. The amount of outstanding fines was said to be so high that some individuals would have lost

---

[11]At a meeting of the organization in June 1983, he spoke out boldly about the injustice of his having to pay a cash fine instead of being allowed to work on the system. He did not ask that the fine be waived, only that it be reduced below the ordinary fine rate since he was not willingly or irresponsibly absent. While there was a good bit of discussion of the issue, the policy was not changed.

livestock or even land if their payment had been enforced. Instead the members decided to burn the records and start afresh.

Decision Making. All important decisions regarding the operation of the Raj Kulo system are taken at meetings of the entire organization. A quorum of at least 50 percent of the members is required for the organization to make binding decisions. One meeting is always held on the first day of Jestha, the second month in the Nepali year, which is mid-May. At this meeting the officers for the coming year are selected, accounts of the previous year are presented, the date for beginning the annual maintenance work is set, and any other items of importance are discussed. Meetings are convened at a traditional, designated location--under the trees at the main saacho which divides the water in half between the two main parts of the system, Ranuwa and Rabidas.

Meetings are very participatory with many members speaking.[12] They may be chaired by the chairman (mukhiya) of the organization, but more often another prominent member is chosen to act as chairman. Formal resolutions are drafted, presented, and voted on. Votes tend to be of a consensus nature. After much discussion, all in agreement are told to signal approval by clapping. If the response is adequate, those opposed are not asked to so indicate. If the response is not overwhelming, there will be more discussion. There are strong, opposing political factions in Argali, but they are able to discuss and make decisions together concerning the operation of the irrigation system.

In the case of particularly complex issues or projects, a special committee may be nominated and selected to develop a proposal or plan and

[12] It was somewhat of a surprise to hear the one low-caste member speak out so boldly concerning what he considered unfair treatment, as was mentioned above.

to oversee its implementation. For instance, a construction committee was appointed in anticipation of the organization being responsible to manage the rehabilitation project which the Department of Irrigation, Hydrology, and Meteorology carried out in the spring and early summer of 1982.[13] Later that year, the organization decided to sell water rights in the system and appointed a committee to work out the details and conduct the sale.[14] Committees are carefully chosen to be representative of the different communities and factions within the organization.

Conflict Management. An irrigation organization which must distribute a limited amount of water to many members and which requires the cooperation of the members for operation and maintenance will inevitably experience conflict. Farmers may try to take more than their allotted share of water, thus depriving someone else. Members may also fail to contribute the required amount of labor and cash for the maintenance of the system.

The rules and procedures of the Raj Kulo organization are designed to minimize conflicts. Distribution of water by *saachos* is a good example. If the farmers served by a field channel can distribute the water among their fields without conflict, a *saacho* will not be installed. However, if they are in conflict over the distribution of water, members who are not involved in the dispute will be asked to help design a *saacho* with appropriately sized openings, and it will be put in place. The practice of having all concerned farmers present when a *saacho* is fixed in place each year reduces the likelihood of conflict over the size and placement of it.

---

[13]To the complete surprise and anger of the organization, a contractor was awarded a contract for this work, and he brought in laborers from outside the community. The Raj Kulo organization, which could have handled the project much better, was completely ignored.

[14]The committee functioned well, but as shall be discussed in Chapter 7, the sale was never completed.

In the event that water stealing does take place, the chairman and secretary of the organization are to be informed. An emergency meeting of the organization will be called, at which attendance is compulsary, and punishment will be decided upon. In the minutes of the Raj Kulo organization were found several accounts of persons being apprehended stealing water by making unauthorized breaks in the canal bund. The records included signed confessions by the guilty parties and statements of their willingness to accept punishment and make compensation as decided upon by the members of the organization. These dated from some 20 years previous. The water supply is now so adequate that stealing is not a serious problem.

To ensure that members contribute their share of the labor to maintain the system, attendance records are maintained and fines imposed for absence. The attendance record is to be available for all to inspect in case there is a dispute over the fines. Periodically, two members are assigned to collect all outstanding fines.

In organizations of all kinds, the handling of cash is a potential source of mistrust and conflict. The requirement that the secretary make a public accounting each year and the appointment of an audit committee to check the accounts minimizes suspicion that money is being embezzled, reducing if not eliminating a common source of conflict.

3.3.4 Organizational Structure

Officers/Functionaries. All farmers cultivating khet fields which have an allocation of water from the Raj Kulo are equal members in the Raj Kulo organization. Each year at the annual meeting, the organization selects a number of officers and functionaries to fulfill certain designated responsibilities. The mukhiya (chairman) is responsible for organizing all of the maintenance work and for calling the meetings of the organization. He may chair the meetings or arrange for someone else to do so. Judging from the minutes that were available, he chairs about half of them.

The bahidar (secretary) keeps the attendance records, accounts, and the minutes of the organization's meetings. He is also the cashier for the organization. There was a time when both the mukhiya and bahidar were from Rabidas, the lower half of the system. However, there is now a convention that the mukhiya will be from Rabidas and the bahidar from Ranuwa, the upper half of the command area.

Two pale theknes are selected, one from Ranuwa and one from Rabidas. They are responsible to see that every day during the monsoon season one person from each of the two areas is assigned to patrol the canal. One pahiro jaachne is selected who checks landslides and reports their severity to the mukhiya.

A pani jaachne is designated to check that the two persons who are to patrol the canal actually go and do their work. If they have not reported to the main saacho by 11:00, he sends another person. A fine of Rs. 8 is collected that very day from the person who failed to go to work and is paid to the one who went in his place. Formerly, the pani jaachne would measure the canal flow with a stick, and it was the responsibility of the persons patrolling the canal to see that the supply was sufficient to reach the top of the stick. This is no longer done because the flow has been increased significantly. The pani jaachne also stores the organization's tools.

A three-man audit committee is appointed every year to examine the accounts which have been maintained by the bahidar. Both Ranuwa and Rabidas are represented on the committee.

With the exception of the audit committee, all persons holding a position receive some form of remuneration. For each day of maintenance, the *mukhiya* and *bahidar* receive credit for two laborers and are excused from doing physical work; however, they have to be present. Thus, if their water allocation requires them to provide two laborers each day, they then have to send none. On the other hand, if they are required to send only one, they are credited with having provided one and, in addition, are paid the equivalent of one day's wages for every day of maintenance work. The *pale theknes* are credited for one laborer each and are excused from doing physical work. The *pani jaachne* and *pahiro jaachne* are each paid Rs. 60 for the monsoon season.

These different functionaries are chosen each year and may succeed themselves. The current chairman has held that position for many years, and before him it was occupied by his father.

Meetings. The annual meeting which is held in mid-May has been described above. Formerly when the annual routine maintenance of the system took longer, this meeting was called for a month earlier. Some years the business of the annual meeting cannot be completed in one afternoon session, and the organization will meet two or three times within a week or so. Special meetings may be called at any time that there is a decision needed or an issue to be discussed.

Records. The Raj Kulo irrigation organization maintains various types of written records which proved to be an invaluable source of information about the function and structure of the organization. The most important and accessible records are the registers in which members' attendance at maintenance work is recorded. These include each member's name, the number of *muri* of his water allocation, and a record of the days on which he was present at both routine and emergency maintenance. These records have been traditionally recorded and kept by the secretary, but recently it was decided that the chairman should also keep a record of the members' attendance. This may reflect somewhat a lack of trust between members from Rabidas and Ranuwa.

The secretary also maintains a written record of all cash receipts and expenditures as well as loans that have been made to members from the organization's treasury. He makes a financial report each year by reading aloud all of the entries at the annual meeting. The accounts are audited each year, and the secretary is held responsible for any discrepancy between receipts, expenditures, outstanding loans, and cash on hand. The accounting procedures were tightened up and the audit instituted after a former secretary had been discovered stealing money from the organization.

Minutes of the meeting with a list of the agenda items and the actions taken are also kept by the secretary. These minutes are signed by all members present at the meeting. Since a number of the members cannot write, their names are recorded along with their thumbprints.

In 1983, a committee consisting of the headmaster of the high school and the Pradhan Panch (chairman of the local government council)--both of whom are members of the organization--was appointed to draft a constitution for the Raj Kulo system. This constitution does not represent new rules but rather a complete and systematic statement of the principles and rules by which the Raj Kulo system has been operated for a number of years. The constitution, which was adopted by the members, is included as Appendix 3.

This description of the Raj Kulo irrigation system reveals an organization that is highly structured and effective. The structure and operation of the other three organizations in Argali are very similar to that described for the Raj Kulo.

We will now turn to the other three primary research sites. The description of the farming and irrigation systems in these sites will not be as lengthy as this one of Argali because they are in many ways similar to Argali. Thambesi is the most different from Argali and will require a more detailed description than Chherlung and Majuwa.

3.4 Chherlung

3.4.1 Physical Setting and Population

Chherlung is the research site nearest Argali in terms of geographical location, complexity of irrigation systems, amount of water supply relative to the area that could be irrigated, and farming system. It occupies several river terraces at different levels along the Kali Gandaki river in Bougha Gumha Village Panchayat about six kilometers east of Argali. Like Argali, it is about a half-day walk from Tansen, but there is no vehicular traffic to Chherlung. The trail runs north from Tansen along the Brangdhi Khola stream and passes above Ranighat at the confluence of the Kali Gandaki and Brangdhi Khola before arriving in Chherlung. Most marketing, including the purchase of agricultural inputs, is done in Tansen.[15]

Nearly all of the households owning khet in Chherlung reside in Wards 1, 2, and 3 of Bougha Gumha Panchayat. In 1983, an all-household census was conducted of these three wards by the researchers. It tabulated 199

---

[15]The Argali chapter of the national agricultural coop (sajha) is the one which is to serve Chherlung, but most people from Chherlung buy fertilizer and other goods from dealers in Tansen. In 1984, one of the irrigation organizations in Chherlung became a fertilizer dealer. It took a loan to buy fertilizer and sold it to member farmers on credit for using on the wheat. After the harvest, the individual farmers were to pay off their loans, and the organization would pay back the loan from the bank.

households with a total population of 1278. As in Argali, Brahmins are the dominant group, accounting for almost 60 percent (117) of the households, followed by Magars numbering 38 households, Majhees 30, Chhetris 6, and the occupational castes only 8.

The total land area of Chherlung is 270 hectares, but less than a third of it is suitable for cultivation. The remainder is rocky with steep slopes and can be used only to produce fodder. There are three irrigation systems in Chherlung which irrigate a total of 61 hectares of khet and 13 hectares of bari. An additional 9 hectares of bari, which lie above the irrigation canals, are also cultivated. The oldest irrigation system is fed by nearby springs. The other two systems, the Thulo Kulo (large canal) and Tallo Kulo (lower canal) have their intakes six to seven kilometers away on the Brangdhi Khola. The total area of khet irrigated by the Thulo Kulo is 34.8 hectares and by the Tallo Kulo, 17.9 hectares. The 13 hectares of bari that are irrigated during the winter and spring are on steep slopes; however, they may eventually be converted into khet by carving out bunded terraces. This process of changing bari into khet has gone on continuously since the canals were first completed approximately 50 years ago.[16] Table 3.5 summarizes the Chherlung irrigation systems.

Table 3.5 The Chherlung Irrigation Organizations

System	Command Area (ha)	Khet (ha)	Total Farmers	Constraint to Expansion
Thulo Kulo	41.7	34.8	105	Water
Tallo Kulo	23.9	17.9	58	Water
Saplak	8.0	8.0	-	Land

[16]While on a brief visit to Chherlung in March 1985, I observed a small parcel of bari being converted to khet in the Thulo Kulo system.

The irrigated fields in Chherlung lie on four distinct levels.

1. The lowest irrigated area is just above the present flood level of the Kali Gandaki. It consists of less than 8 hectares and is the area served by the spring-fed system. This system was developed prior to the construction of the Thulo Kulo and Tallo Kulo systems.

2. The first river terrace is at an elevation of 80 to 100 meters above the Kali Gandaki. The tail section of the Thulo Kulo system is on this terrace.

3. Higher up at an elevation of 150 to 170 meters above the river is a terrace which forms the middle part of the Thulo Kulo system.

4. Still higher at an elevation of 200 meters above the river is a saddle area between the high hills to the south of Chherlung and a hill in the middle of the river terrace. The majority of this is irrigated by the Tallo Kulo system, but a portion of it forms the head end of the Thulo Kulo system.

Figure 3.3 shows the area that is irrigated by each of the three irrigation systems.

3.4.2 Farming System

The farming system in Chherlung, including the cropping pattern, agricultural calendar, varieties planted, and livestock husbandry, is nearly identical to that of Argali. This is because the environment--physical, social, and economic--is also similar to that of Argali. The most critical factor that makes the farming system in Chherlung more like that of Argali than of its neighbor Piugha directly across the river is the water supply in the Brangdhi Khola which makes irrigation possible year around.

Cropping Pattern on Khet. As in Argali, the predominant cropping pattern on the khet land in both the Thulo Kulo and Tallo Kulo systems is monsoon rice, winter wheat, and pre-monsoon maize. There is not sufficient water in the Brangdhi Khola to allow many farmers to grow rice during the pre-monsoon season, and the rule giving priority to irrigation of maize effectively prohibits rice cultivation. However, the small, spring-fed

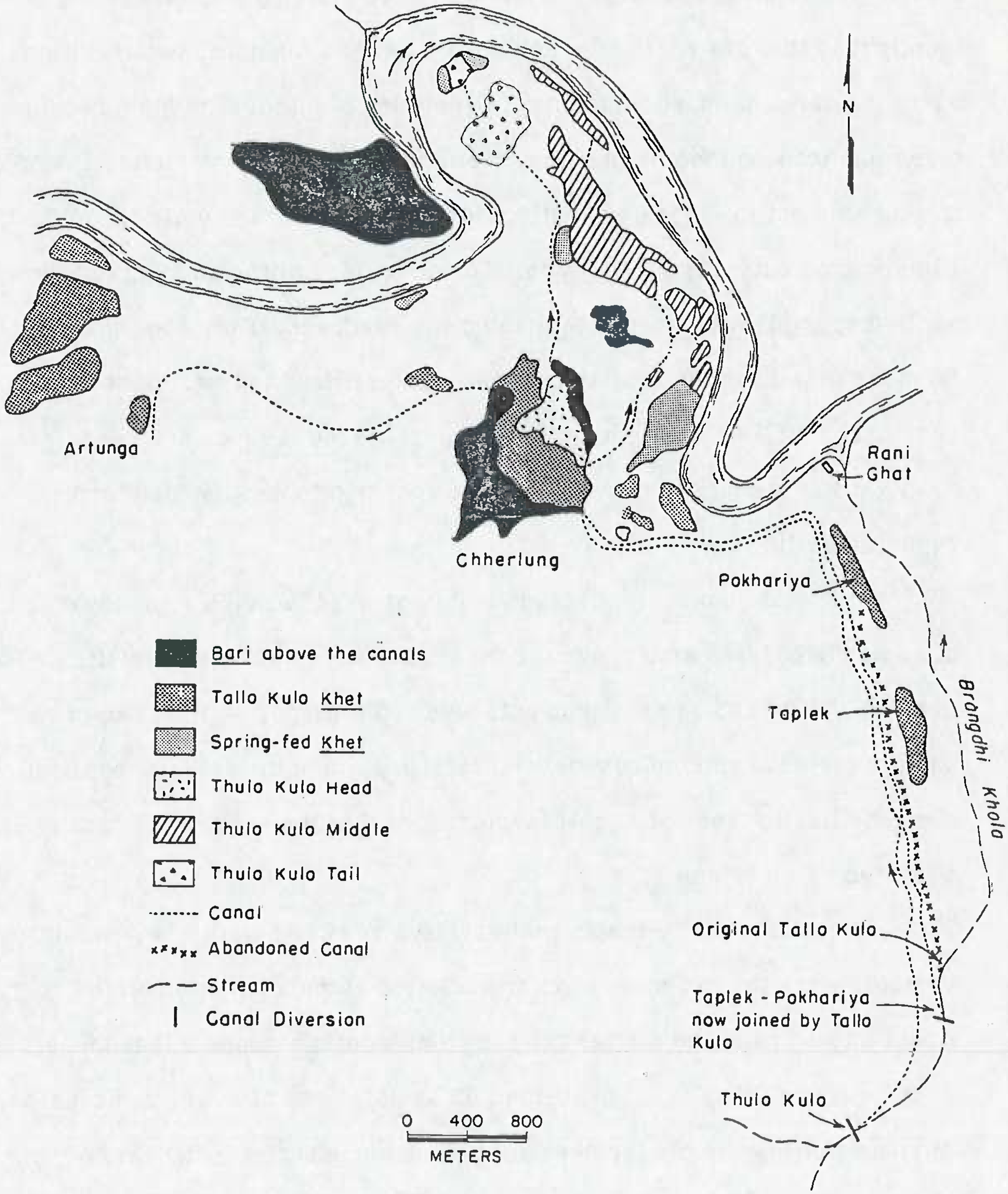

Figure 3.3 Chherlung Irrigation Systems and Land Types

system has relatively more water in this season, and rice is planted over most of its command area. The timing of crop planting and harvesting is identical to that of Argali. Chherlungi Yellow and Ampjote, two traditional varieties, are the most common rice varieties planted. The main reason given for growing them is that they yield more than other varieties. Ampjote is also said not to lodge as readily. In 1982, the average yield from the 121 sample crop cuts was 3.5 tons/ha. Three-fourths of the 35 sample farmers applied asuro leaves when establishing the seedbeds. Only about half of the farmers in the sample applied commercial fertilizer to the rice crop, and none used FYM. All of the sample farmers weeded the rice crop one time. Nearly all of the rice is grown for home consumption--only four farmers reported selling any.

The most commonly planted variety of wheat was RR21, as in Argali, but some UP262 was also grown. Both of these are improved varieties. The average yield of 95 sample crop cuts was 2.5 tons/ha. All but two of the sample farmers applied commercial fertilizer, and the rates of application were similar to those of Argali farmers. Half of the sample farmers reported sales of wheat.

Bergelli White, a traditional variety, and Rampur Yellow, an improved variety, were the two most popular varieties of maize planted on the khet. About one-third of the farmers in the sample intercropped a legume as a green manure. The average yield of 95 sample crop cuts was 2.4 tons/ha. Over half of the sample farmers applied no commercial fertilizer to their maize crop, and 62 of the crop cut samples came from fields without fertilizer. All farmers applied FYM to the maize. Only eight of the farmers reported sales of maize. Maize is the second most important grain in the diet, and some is fed to livestock. Table 3.6 summarizes the results of the crop cuts that were taken from the _khet_ fields in the Thulo Kulo system. The average total yield per hectare was 8.4 tons of grain.

Table 3.6 Sample Crop Cuts, Chherlung _Khet_

	Rice	Wheat	Maize
Number cuttings	121	95	95
Planting date[a] - mean	27/7	7/12	17/4
Harvest date[a] - mean	16/11	10/4	20/7
Yield[b] - mean	3.5	2.5	2.4
minimum	0.7	0.7	0.3
maximum	7.2	4.8	5.8
s.d[c]	1.1	0.8	1.0

[a](day/month) [b]tons/ha [c]standard deviation

Cropping Pattern on Irrigated Bari. There is much less irrigated _bari_ in Chherlung than in Argali due both to the topography and, as shall be argued later, the different principle of water allocation. Not very many members of the Thulo Kulo irrigation organization have irrigated _bari_ fields--of the sample farmers only 10 did. In the winter of 1982-3, only five of these grew wheat. All of them planted maize on these fields in April or May and harvested it in September. Three of them planted a relay crop of millet in August which they harvested in April. No crop cuts were taken in _bari_ fields--irrigated and unirrigated--in Chherlung.

Cropping Pattern on Unirrigated Bari. Two-thirds of the sample farmers cultivated unirrigated _bari_ fields. In 1983, all of them planted maize in April or May and harvested it in September. Half of them planted a relay crop of millet which they harvested in November. Two farmers followed the maize harvest with a crop of mustard harvested in December, and three grew a rainfed crop of wheat which was planted in December and harvested in April.

Livestock. The number and types of livestock raised in Chherlung are very much the same as in Argali. As in Argali, they are stall-fed, and collecting fodder is a time-consuming task. Farmers in Chherlung reported that they raise fewer livestock than farmers across the river where there is no irrigation because maintaining the irrigation system requires so many days of work. This reduces the time that is available to gather fodder to feed the animals.

3.4.3 Irrigation Management Activities

The following description of irrigation organization in Chherlung will focus on the Thulo Kulo system. It is the largest system, and it and the Tallo Kulo system are organized nearly identically. The small spring-fed system requires very little organization for two basic reasons: (1) its water supply is plentiful relative to the size of the command area, and (2) because the source is a spring very near the command area, hardly any resources need to be mobilized for system maintenance.

Water Acquisition - Construction. The original construction of the canal for the Thulo Kulo system was begun in 1928, and water first flowed through the 7-kilometer-long canal to Chherlung in 1933. It was, thus, possible to interview men who were living at that time and who participated in the original construction work. Prior to construction of the Thulo Kulo system, there was little irrigation in Chherlung, and agricultural production was not very intensive. Most households were said to have been food-deficit, and it was reported that people left the area because they were not able to produce enough food on the unirrigated bari.

Two individuals, Pursottam Bhattarai and Krishna Bahadur K.C., receive the credit for initiating the plan to construct the system, contributing a large share of the initial investment and managing the 5-year construction project. Because of the technical difficulty of constructing the canal which had to be started at a point far from sight of Chherlung and which was cut into the face of sheer cliffs at places, many people were skeptical of its feasibility and unwilling to contribute. Only an additional 25 households could be convinced of the value of the project and contributed toward the original construction contract.

Agris from Damukh Khani in Gulmi District were contracted to "design" and supervise construction of the canal. The contract included Rs. 5,000, food for them and the laborers they brought from Damukh Khani, and a small parcel of land.[17] The two initators of the project reportedly sold jewelry and some land to raise most of the money for the contract. One of the agris, a young blacksmith credited with constructing several canals in this region of Nepal, is said to have established the site of the intake and alignment of the canal by climbing a nearby hill from which he could see both Chherlung and up the Brangdhi Khola. After fixing the location of the intake, he reportedly sighted through the jungle and along the cliffs, marking the alignment with stakes, until he arrived at the top of the Chherlung fields.

In addition to the technical difficulties of construction, there was also some opposition to the project. The trail from Tansen to Ranighat, at the confluence of the Brangdhi Khola and Kali Gandaki, follows the Brangdhi Khola, crossing the Thulo Kulo at its intake. This trail was fairly heavily traveled, especially by Tansen residents and others from neighboring

---

[17]The size of the land was said to have been 10 dhan muri, i.e., an area of land that would produce 10 muri of rice or about 500 kg. They were said to have sold the land for Rs. 400.

villages who carried their dead to Ranighat for cremation. People feared that the canal, which runs parallel and above the trail for several kilometers, would continually leak and cause damage to the trail, also making it dangerously slippery. Work was stopped at one point because of this opposition to the canal. Several workers were also arrested on the charge that they were illegally cutting trees from the forest and burning them in order to heat rocks so that they could be broken more easily.

The two influential men who organized the project went to Tansen to plead their case with the representative of the national government. A settlement was reached according to which the irrigation organization agreed to repair any damage to the trail.[18] An official government order was issued forbidding anyone from obstructing the construction of the canal and granting the organization a right-of-way 10 haat[19] wide above and below the canal alignment. Authorization was also given to cut timber for use in the construction.

When water first flowed through the canal to Chherlung in 1932, a large feast was held to celebrate the occasion. Rs. 100, a substantial sum of money in those days, was reportedly spent for the feast. Work commenced immediately to enlarge and improve the canal. It had been built to deliver only a small flow to demonstrate the feasibility of the project. The agri

---

[18]The ruling also stated that funeral processions had the right to stop the flow of water into the canal on their way to Ranighat. They were then to restore the flow on their return trip. However, in practice, they often failed to do so. This was a continual problem for the irrigators who would find the supply suddenly cut off and would have to send someone to investigate. The organization finally took the case to court and received a settlement prohibiting anyone from diverting the supply from the system. In return the organization is responsible to prevent leakage which would cause the trail to become slippery.

[19]A haat is a traditional unit of length equal to the distance from elbow to fingertip or about 18 inches.

contractors were retained for several years to maintain and upgrade the canal during the monsoon.[20] Since that time, there have been other occasions when the organization has given out contracts for digging tunnels or widening the canal. Gradually, over the years, a considerable amount of the canal has been lined with cement. This incremental approach to improvements has allowed concentration of resources on the weakest segment of the system each year and maximization of the use of local labor.

Water Acquisition - Maintenance. The maintenance schedule and needs are similar to those of the Raj Kulo system in Argali, but the amount of maintenance required and the degree of danger are higher in Chherlung because the canal is longer and passes through more difficult terrain. Daily life is very much affected by the need to maintain the canal. In the words of one farmer, "Our livelihood is dependent on the canal, so we respond night or day to its demands."

Routine maintenance to prepare the system for the monsoon season is conducted in June. In a typical year it takes about 15 days to clean the weeds and silt from the canal, improve weak spots in the walls, and repair the intake and saachos. At maize planting time in April, the supply in the Brangdhi Khola is at its lowest ebb, and the canal and intake need to be repaired to achieve as high as possible diversion and conveyance efficiencies. The canal is cleaned and special attention given to repair all leaks. In the spring of 1983, inspection of the canal and diversion several days after this maintenance was completed revealed only three spots in the canal where there was minor seepage. The diversion had been sealed with clay, and the dry stream bed below the diversion attested to its effectiveness

[20]During the dry season in these years, they were constructing the canal for the Tallo Kulo system.

in capturing the surface flow.[21] Flow measurements at each end of the canal indicated that 88 percent of the surface flow in the stream at the diversion was reaching the command area that day.

The Thulo Kulo organization has the canal patrolled every day throughout the year. During the monsoon season, two men make the trip to the intake and back, while for the rest of the year, only one man does. This work was formerly done on a rotational basis by the members, but for several years the organization has been hiring men to do this--one who works all year and one for only the four months of the monsoon rice season. As in Argali, these men do minor maintenance and provide an early warning when disaster strikes requiring emergency maintenance.

During the monsoon season, there is often damage to the system from flooding, landslides which destroy a section of the canal, and falling rocks which block the canal. Falling rocks cause the water to back up and overtop the bank, quickly eroding a section of the wall if the water is not turned off at the intake. Emergency repairs must be made quickly to maintain an adequate supply of water for the rice crop.

Water Allocation. Unlike any of the other systems studied intensively, both the Thulo Kulo and Tallo Kulo organizations allocate water through the sale of shares in the system. Members purchase shares or fractions thereof which entitle them to a specified proportion of the supply in the system during the monsoon rice season. Most transactions are between individual farmers, but the organization has also sold shares, increasing the total number of

---

[21]Water reappeared in the stream a short distance below the diversion, indicating that there was flow through the bed under the diversion. Capturing all of the flow with a concrete or masonry weir would be costly, if not impossible.

shares in the system. The details and implications of this principle of water allocation will be discussed in Chapter 7.

Individuals who have not purchased shares in the system are permitted to use water for irrigating winter wheat and pre-monsoon maize, the same as nonmembers are in Argali. In the same way that members of the Raj Kulo system have first preference for irrigating their <u>khet</u> fields during these seasons, shareholders in Chherlung, also, have first preference over others if they want to irrigate at the same time. The water supply in the Brangdhi Khola is sufficient in the winter to irrigate wheat on the whole command area on a demand basis. Farmers decide among themselves when each will be able to irrigate, and, because of the adequacy of the water supply, there are few conflicts.

Timely planting of the pre-monsoon maize crop is essential if it is to mature in time to transplant the rice. The scarce water supply at this time makes it impossible for all the farmers to irrigate all their fields in preparation for planting maize exactly when they would prefer. Responsibility for allocating the water at this time is vested in the <u>mukhiya</u>. He decides who can irrigate when and how many terraces of their fields they can irrigate. Irrigation for maize begins in the fields while the wheat is still standing, and priority is given to the fields which are nearest to being harvested. The <u>mukhiya</u> collects requests for irrigation and decides, based on the flow in the system, how much land can be covered in the next 24 hours. He limits the allocation of each farmer to a few terraces in a field so that more farmers can plant some of their maize at the desired time. The <u>mukhiya</u> has been given full control of water allocation for this period and says it is by far the most demanding aspect of his work.

Water Distribution. The water supply relative to the area that is irrigated is less in the Thulo Kulo system than that of the Raj Kulo in Argali, and, consequently, the method of distribution is different. In the Thulo Kulo system, saachos are used to apportion the water from the main canal into secondaries. The notches in the saachos are cut so that throughout the system one inch of notch represents one share. As shares are bought and sold, the allocation of water among the secondaries may change, necessitating the modification of saachos to distribute the water according to the new allocation. Openings in saachos can be enlarged as needed by simply cutting them larger, but somewhere in the system another opening must be made correspondingly smaller. Sometimes this is accomplished by nailing a wooden block in the opening, but frequently a complete new saacho must be made.

In 1982, distribution within some of the secondary channels was by continuous flow in the first part of the monsoon season, but all secondaries shifted to rotational distribution around the middle of the season if they were not already rotating. Prior to the change the supply had been interrupted for several days allowing some fields to dry to the extent that the soil cracked. After cracking it was not possible to supply enough water to maintain continuous standing water because of the greatly increased rate of percolation. Distribution by rotation was necessary. One rotation cycle was 36 hours. To find the length of turn represented by one share, the total number of shares within a secondary is added up and divided into 36. The length of each person's turn is then computed accordingly based on the number or fraction of shares he owns. Making the total rotation 36 hours means that turns alternate from day to night rather than having some people always irrigating at night.

As was implied by the discussion of water allocation, water is distributed by rotation for wheat and maize. The rotation is not of any particular order nor strictly timed to match the share allocation, as it is for rice.

Resource Mobilization. The same proportionality principle for resource mobilization is found in Chherlung as in Argali. Labor and cash assessments are made according to the number of shares in the system a member owns. For routine maintenance, a member owning one share is required to supply one laborer each day. A member with two shares is responsible to provide two laborers each day of routine maintenance. When emergency maintenance is called for, all member households are required to send one laborer. The number of man-days of labor mobilized each year for routine maintenance, patrolling the canal, and emergency maintenance is very high, averaging a total of almost 2500 man-days a year for the past three years. Written attendance records are kept, but only two years of these records were located and copied. A third year's figure was extrapolated from these on the basis of the number of days of maintenance work in each of the three years.

Low-caste members are not prohibited from performing maintenance work on the Thulo Kulo system in Chherlung as they are in Argali. The system was not built to support a temple as was the Raj Kulo. Women, however, do not participate in the maintenance work. The reasons given for this restriction were that it is dangerous and difficult work and that it is not proper for men and women to be working together in isolated places rather far from the village.

The Thulo Kulo organization has frequently raised cash from the members to pay for improvements made to the system--most often the cash is used to purchase cement to line or reinforce sections of the canal. The amounts assessed per share in 1982, 1983, and 1984 were Rs. 250, Rs. 580, and Rs. 150 respectively. Cash was also raised one year by selling 10 more shares in the system at a rate of Rs. 2800 per share. The district panchayat has given cash grants several different times. Table 3.7 lists the cash investments that have been made in the system. The early figures were taken from members' recollections while the more recent were available from the records of the organization.

The amount of resources mobilized per hectare in the past several years has been extremely high. If the average number of man-days per year is converted to cash at the average daily wage rate for men of Rs. 10, the total value of labor mobilized per year is Rs. 25,000. A total of Rs. 89,800 in cash assessments has been raised over the past ten years for an annual average of Rs. 8,980.[22] Thus the average annual value of resources mobilized totals Rs. 33,980 or approximately Rs. 975 per hectare of khet. This is substantially more than the assessment of Rs. 60 per hectare per crop in the systems under the Department of Irrigation, Hydrology and Meteorology.

[22]This includes regular assessments and fines but does not include the Rs. 28,000 from the sale of an additional 10 shares.

Table 3.7 Cash Investments in the Chherlung Thulo Kulo System[a]

1928-1932	Construction contract	Rs. 5,000
	Land for contractors	400
	Food for celebration feast	100
1932-1938	Canal improvement contract	3,600 [b,c]
	Value of food provided contractors	2,000
1942	Contract to dig tunnel	500 [c]
1943	Contract to widen canal in places	1,000 [c]
1956	Contract to widen canal near intake	3,000 [c]
1959	Contract to widen canal in rock cliff	1,300 [c]
1967	Landslide repair using cement in the system for the first time	3,800 [c]
		3,800 [d]
1975	Canal lining	10,000 [c]
		18,000 [d]
		8,000 [e]
1978	Canal lining	7,000 [e]
		28,000 [f]
1981	Canal lining	15,000 [c]
		12,500 [d]
		6,000 [e]
1983	Landslide repair	34,800 [c]
		30,000 [d]
1984	Intake improvement	9,000 [c]

[a]Exchange rate, January 1983: US $1.00 = Rs. 14.20.

[b]Original contractors were retained to improve and maintain the canal during the monsoon rice season.

[c]Cash raised by assessing members on the basis of shares owned in the system.

[d]Grant from the district panchayat.

[e]Income from collection of fines. Fines were levied mainly for failing to provide the required number of laborers for maintenance work.

[f]Income from sale of additional ten shares in the system.

Decision Making. As in Argali, all major decisions are made at meetings of the entire membership. Attendance at some of the meetings is compulsory, and members who are absent are fined. If the man of the household is unable to attend, his wife may attend in his place and no fine will be assessed. There is also an eleven-man committee which makes some decisions such as setting the price of shares. At the meetings which were attended by the researchers, the Brahmin and Chhetri (high caste) members certainly dominated the discussion, and the Majhees did not speak up at all.

Conflict Management. The rules of the Thulo Kulo organization have been developed over time to enable the organization to mobilize resources and to minimize and resolve conflicts. According to the members, the initial rules remain largely unchanged, and only the magnitude of the fines has been revised periodically to adjust for inflation.

Due to the topography of the area, only a few fields border the main canal. Therefore, there is relatively little stealing of water from it. A strict fine of Rs. 50 is levied on any person caught tampering with the main canal and/or a saacho. Stealing water from within a secondary canal rotation group is more common and almost expected when a farmer does not closely supervise the delivery during his turn in a period of short supply. Such conflicts are worked out within the rotation group. If it cannot be resolved within the group, the problem is taken to the mukhiya. Usually no fine is assessed, but the offended is allocated a portion of the offender's water in the next rotation.

Until a piped drinking water system was installed in 1983, the canal was the main source of drinking water for many of the residents of the lower part of the system. There is, thus, a rule against dirtying the canal in any way, and a fine of Rs. 5 is imposed if one is apprehended polluting the water.

Failing to provide a laborer when required for routine and emergency maintenance results in a fine. The fine for missing routine maintenance is set at approximately the daily wage rate--Rs. 10 in 1982--and for missing emergency maintenance somewhat higher--Rs. 12. If the person is absent from the community on the day an emergency is declared or has some other acceptable excuse, then the fine is reduced to Rs. 6.

Payment is due promptly upon the assessment of a fine, and all fines are collected. In an early year of the system's operation, one man failed to report for emergency maintenance several days in a row. When his fine was levied, he refused to pay it. A group of the members then went to his house and confiscated his cooking pots, and he was told they would be sold in lieu of his payment of the fine. Within a short time he paid the fine and recovered his utensils. This example, plus the threat of cutting off an individual's water supply, has prompted 100 percent payment of fines.

With the major improvements that have been made to the canal since 1978, the water supply has been relatively adequate and reliable. As a result, conflicts related to water distribution have been greatly reduced. The main source of conflict in the past few years has been the adjustment of the rotation period after the supply has been interrupted for a period. Depending on how long the water has been off, farmers may be concerned about moisture stress to their crop. The rotation cannot just pick up where it was interrupted and continue with the same length of turns because those who have to wait until the end of the rotation may then be without water for a significant period of time. Some adjustment is required if equity is to be served, and working this out when everyone is desperate to irrigate has caused conflicts.

3.4.4 Organizational Structure

Officers/Functionaries. The membership of the Thulo Kulo irrigation organization consists of all households owning at least a fraction of a share in the system. Shareholdings range from one-eighth of a share to four shares, and in 1982 there were 105 members. The members are organized into seven groups with each group named for a different day of the week. Each group is responsible for the operation and maintenance of the system on the day for which it is named. Membership in each group is carefully chosen so that there is representation from all parts of the command area. This is a check to ensure that all parts of the system are equally served each day. Groups are also formed so that each represents approximately the same number of shares, since labor contributions are to be in proportion to shares owned. The same number of workers are, therefore, available for work on each day. Formerly, the members of the groups would take turns, two by two, patrolling the canal during the monsoon season, but for several years now, two people have been hired for this job.

Each of the seven groups has a leader referred to as a thari who is selected by the organization as a whole.[23] In addition to the seven thari, two other officers of the organization and two honorary members form a canal management committee. The mukhiya is responsible to plan and organize all the maintenance work, allocate water for maize planting, and call meetings of the organization. He is also the final authority in settling disputes.

---

23 Formerly, a thari was a nonofficial tax collection functionary in the hill districts (Regmi, 1978). Perhaps the persons occupying the position of thari in the irrigation organization at one time also fulfilled this tax collection function.

Grievances that cannot be resolved by a rotation group or *thari* are brought to him. As necessary, he consults with the rest of the canal committee and administers justice. The present *mukhiya*'s father was the original *mukhiya* of the organization and is credited with developing the procedures by which the system functions. Like the *mukhiya* in Argali, he is excused from two shares of work as remuneration. Similarly, the *thari* are credited with one-fourth of a laborer as remuneration.[24]

A *sachiv* (secretary) fulfills the same functions as the *bahidar* in Argali. He maintains the attendance records, accounts, and minutes of meetings. In addition to these records, he must keep a list of members' shareholdings and record any transactions of shares in the system including the locations from and to which water must be transferred. Members' shares must be recorded according to the secondary within which they are located, and each member's holdings across the secondaries must add up to his total shareholding. The man who was *sachiv* when the research was being conducted was a skilled carpenter and made most of the adjustments to the *saachos* that were required following transactions. Until 1967, the *mukhiya* did all of the work that the *sachiv* now does. That was the first year that the organization received assistance from the government, and it was required that a person be appointed to account for the grant. Since then, the *sachiv*'s responsibilities have gradually expanded. The *sachiv* is excused from all physical labor connected with the operation and maintenance of the system as remuneration for his work.

---

[24] In Chherlung, those who are excused from work as remuneration for filling roles in the organization are not paid the difference between the number of laborers credit which they receive and the number they are responsible to provide, if this number is less, as they are in Argali. They are also not excused from the cash assessments that are made on the basis of shareholdings.

The officers serve at the pleasure of the members and can be replaced at any time if there is dissatisfaction with their performance. There has been, however, little change in the officers. At the time of the research, the sachiv was only the second one to hold the position, and, as was mentioned, the mukhiya was the son of the first mukhiya. In 1985, however, an annual election of officers was initiated. Two men were nominated for mukhiya including the current one. Instead of holding a vote to select one of them, however, it was decided that the job of mukhiya was sufficiently demanding to justify having two men in the position as co-mukhiyas. The current sachiv decided he was too busy farming and running a small shop and refused to allow himself to be nominated.

The two honorary positions on the management committee were originally held by the two founders of the system. Because these two men also fulfilled the role of jimmawal (a nonofficial functionary who collected taxes on khet lands in the hills) in the community, the two honorary positions are called jimmawal. The sons of the two founders served the government in that role until it was abolished in 1977. They continue to hold the honorary positions on the committee where they are available for consultation and are excused from three shares of labor. The fact that these hereditary positions remain on the committee and receive such a high remuneration is indicative of the members' high esteem for the founding fathers of their system.

Meetings. A regular annual meeting is held in May to plan the routine maintenance work and review the operating rules for the monsoon season including the setting of fine rates. After the rice harvest, another regular meeting is held at which time accounts are cleared and plans made for any improvements to be made to the system during the winter construction season. Election of officers is a new function that was carried out at a meeting in January of 1985 and is to be done annually. Special meetings are called as necessary. For instance, in 1983, several meetings were called to discuss the installation of a water-turbine-powered mill in a drop in the canal. The organization decided to install the mill to be owned collectively by the members of the organization (proportional shares in the mill to be the same as the shareholdings in the system), and a mill management committee was appointed.

The management committee of the Thulo Kulo organization does not have a regular meeting schedule but meets as needed to settle conflicts or discuss any other item related to the operation of the system which does not require a decision by the full membership. Meetings of the committee were said to take place 5 or 6 times a year.

Records. As in Argali, the organization maintains written records including a membership list, members' shareholdings, an attendance register, and accounts. Unfortunately, considerably fewer records of the past could be located than in Argali. It was said that many had been destroyed in a house fire. The Thulo Kulo organization does not have a written constitution, but all members can explain how the organization functions and many can recount the history of the organization.

The Thulo Kulo and Tallo Kulo organizations in Chherlung are very similar in operation and structure. Both are highly structured and extremely effective irrigation management organizations. The primary way in which they are different from the organizations in Argali is in the allocation of water by sale of shares in the system. The implications of this will be analyzed and discussed in Chapter 7.

3.5 Majuwa

3.5.1 Physical Setting and People

Majuwa and Thambesi bracket Argali and Chherlung both geographically and in terms of the relative water supply. Majuwa to the west of Argali has an extremely abundant water supply whereas Thambesi to the east of Chherlung suffers from a scarcity of water.

Majuwa is a small bazaar in Gulmi District at the confluence of the Hoogdhi Khola and Bari Gad rivers. Access is by a day-and-a-half walk from Tansen on the trail through Argali, and the trek from Majuwa to the district center of Tamgas takes nearly a day. A feeder road to the fair-weather road from Tansen to Tamgas has been completed to within a two-hour walk of Majuwa and will eventually pass through the bazaar. The Majuwa bazaar consists of a number of tea shop-cum-hotels, several stores selling cloth and sundries, a medical hall, a government health post, and a branch of the sajha. There is a branch office of the postal system, and primary through high school education is available.

The command area of the irrigation system which was studied is in Ward 9 of Rupakot Village Panchayat, across the Hoogdhi Khola to the east of the Majuwa bazaar. Socially, economically, and politically, Brahmins and Chhetris dominate the area as well as the irrigation organization. Of the 111 member households of the irrigation organization, over 80 percent are Brahmin and the remainder Chhetri, with the exception of one Magar family. Member households of the irrigation organization are scattered among the wards of Rupakot Panchayat, and many live in hamlets high on the hills which tower above the river terrace. Often farmers have a one- to two-hour walk from home to their fields.

Four irrigation systems are fed by canals from the Hoogdhi Khola in the Majuwa area: two on the east side of the river, one on the west side, and one across the Bari Gad.[25] The Damgha Kulo irrigation system was selected for study because it has the most abundant supply of water. The Hoogdhi Khola is supplied by a large catchment area and does not shrink to a trickle during the winter and spring like many of the monsoon-fed hill streams. Since the command area is on the north side of the Bari Gad, the fields are on a south-facing slope. They are on a river terrace at an elevation of approximately 700 meters. There are terraces at two levels, and the Damgha Kulo system irrigates the upper one and the Sota Kulo system, the lower one.[26] Table 3.8 summarizes the irrigation organizations in Majuwa.

Table 3.8 The Majuwa Irrigation Organizations

System	Command Area (ha)	Khet (ha)	Total Farmers	Constraint to Expansion
Damgha Kulo	28	28	111	Land
Sota Kulo	20	20	120	Land
Turung	15	15	-	Land
Jubung	10	10	55	Land

[25]This last one on the other side of the Bari Gad had been supplied by a small stream on that side of the river. A landslide destroyed a length of tunnel, and the organization despaired of ever being able to open it. With some assistance from the district panchayat; Department of Irrigation, Hydrology and Meteorology; and Ministry of Panchayat and Local Development as well as an impressive amount of their own resources, they were able to bring water from the Hoogdhi Khola. A several-hundred-meter-long plastic pipe brings the water across the Bari Gad on a suspension bridge erected specifically for this purpose.

[26]It was not possible to acquire air photos of the Majuwa area; therefore a figure showing the layout of the command areas has not been included.

3.5.2 Farming System

Cropping Pattern on Khet. The abundant supply in the Hoogdhi Khola results in slightly different production possibilities in Majuwa than in Argali and Chherlung. In the command area of the Damgha Kulo irrigation system, shortage of water is not a constraint to production in any season. All farmers grow monsoon rice followed by a crop of winter wheat. The water supply in the pre-monsoon season is adequate to grow rice over the entire command area, but most of the farmers grow some maize in this season in addition to rice. By visual inspection it appeared that approximately two-thirds of the area was in rice and the remainder in maize. Eight of the 32 sample farmers grew only rice in the pre-monsoon, while two planted only maize.

The agricultural calendar in Majuwa is nearly identical to that of Argali and Chherlung. Monsoon rice is planted and harvested at exactly the same time. The survey revealed that most of the rice grown during the monsoon was traditional varieties with the most popular being one called Battisa. The average yield of 90 sample crop cuts was 3.4 tons per hectare. None of the sample farmers used commercial fertilizer or FYM on their monsoon rice crop. The main reasons given for not applying commercial fertilizer were: unavailable when needed (15 farmers), spoils the soil (14), and lack of money (11). FYM is not used because it is wet and too heavy to carry. It is saved for the wheat and maize crops.

Wheat was planted about a week earlier in Majuwa than in Argali and Chherlung and harvested at the same time. Two modern varieties, RR21 and UP262, were the only ones planted. Forty sample crop cuts yielded an average of 2.2 tons per hectare. Twenty-one of the sample farmers applied no commercial fertilizer to their wheat crop.[27] Reasons given for not using fertilizer were: lack of money (6), unavailable when needed (4), sufficient FYM applied (4), it spoils the soil (3), and it causes diseases on plants (1). Nearly all farmers applied FYM to the fields when planting the wheat. As in Argali and Chherlung, the wheat crop is not weeded, and late in the season, weeds are harvested daily as fodder for the livestock.

Maize was planted at the same time as in Argali and Chherlung, but on the average was in the fields five days longer, i.e., 100 days. Twenty-five of the sample farmers grew maize on the khet in the pre-monsoon season. The average yield of the 34 sample maize crop cuts was 2.4 tons per hectare. Only six of the farmers used commercial fertilizer, and most applied FYM.

Thirty of the sample farmers grew rice during the pre-monsoon season. The mean date of transplanting was April 13 and the mean harvest date, July 21, indicating that the crop was in the fields for 99 days after transplanting. Few farmers--only six--applied commercial fertilizer to their early rice crop. The average rate of application among these was 30 kg/ha of nitrogen and 14 kg/ha of phosphorus. The average yield of 48 sample crop cuts of pre-monsoon season rice was 3.4 tons/ha.

Farmers said that rice in the pre-monsoon season fits the cropping pattern better than maize. According to them it matures in a shorter season,[28] and fields in which there is rice during the pre-monsoon require less water for land preparation for the monsoon rice crop and hold water

---

[27]It is possible that more farmers would not normally have used commercial fertilizer, but some of them were participating in a seed production program. The program, under the Agricultural Inputs Corporation with assistance from USAID, required that farmers apply a specified amount of fertilizer.

[28]The crop cut data do not show the early rice to be a significantly shorter-season crop than maize. Rice was in the field 99 days and maize 100 days. The mean rice harvest date was four days earlier than that of maize.

better than fields in which maize is grown. Yet most of the farmers grow some maize on their khet. The reason given for doing so is that they have a preference for some maize in their diet. Table 3.9 summarizes the results of the crop cuts that were taken in Majuwa.

Table 3.9 Sample Crop Cuts, Majuwa Khet

	Monsoon Rice	Wheat	Maize	Early Rice
Number cuttings	90	40	34	48
Planting date[a] - mean	25/7	5/12	16/4	13/4
Harvest date[a] - mean	16/11	16/4	25/7	21/7
Yield[b] - mean	3.4	2.2	2.4	3.4
minimum	1.3	1.0	0.8	1.4
maximum	5.4	7.1	5.0	5.1
s.d.[c]	0.7	1.1	1.0	0.8

[a](day/month) [b]tons/ha [c]standard deviation

Cropping Pattern on Unirrigated Bari. Because of the plentiful water supply, there is no irrigated bari in Majuwa. All bari in the command areas has been converted to khet. The Damgha Kulo system is land constrained, i.e., it could irrigate more land with its water supply, but there is no more to be irrigated.

All but three of the sample farmers also cultivate some unirrigated bari fields. They plant maize in these fields in April or May, depending on the rainfall, and harvest it in September. A legume is usually intercropped with the maize. Many farmers plant a relay crop of millet on a portion of their maize fields in August and mustard on some of their fields after the maize harvest. The millet and mustard are both harvested in December.

Farmers estimated maize yields on the bari to be 2 tons/ha and yields of mustard and millet, considerably less.[29]

Livestock. Livestock fit into the farming system in Majuwa in the same way that they do in Argali and Chherlung. As will be seen in a later table, the livestock holdings per household are nearly identical in these three sites.

3.5.3 Irrigation Management Activities

Water Acquisition - Construction. The main canal of the Damgha Kulo system is two kilometers long from intake to the beginning of the command area. No information could be found concerning the original construction of the canal. Within recent memory there have been some significant improvements made. In 1956, agris from Bharse in Gulmi District were hired to dig a tunnel through an area where the canal was often damaged by landslides. The amount of the contract was said to have been Rs. 2200. About a week after it was completed, the tunnel was destroyed by another landslide. Some members of the organization then took a contract of Rs. 1900 to reconstruct it.

In 1973, the current leader of the organization took a contract to dig about 45 meters of tunnel. There had been a tunnel in this location close to the surface, but it had been damaged by a landslide. A dozen men reportedly worked for one and a half months to dig it deeper under the surface. The amount of the contract was Rs. 5300.

Water Acquisition - Maintenance. The Damgha Kulo organization has a different arrangement for maintaining the system than any other system studied. Instead of the members working to repair and clean the system, a

---

[29]If the maize here produces similarly to the maize on unirrigated bari in Argali, the Majuwa farmers have considerably underestimated the yield. In Argali the yield of maize on unirrigated bari was 4.4 tons/ha.

maintenance contract is given to several of the members of the organization. This practice was begun in 1970, and the chairman (referred to as the _adhakshya_), his brother, and a friend have had the contract ever since. The members are only called upon to work on the main canal or intake if an emergency repair job will take the three of them more than three days. From 1970 through 1982, the members had not been called out to work at all.[30] The amount of the maintenance contract in 1982 was Rs. 4200.

This arrangement for maintaining the system is appropriate in Majuwa for two reasons. First, the canal is not very long and does not run along slopes subject to landslides for much of its length. Where it does, it has been replaced by tunnel. Therefore, the maintenance requirements are relatively low. Second, many of the members live on the hills overlooking the command area, a distance of as much as a two-hour walk. Calling them to work for emergency maintenance would be difficult, and the walk to and from would be a hardship for them. The organization decided that in this situation, paying to have a contractor be responsible for the maintenance was preferable to having the members contribute their labor.

Water Allocation. Water is allocated in proportion to area irrigated, as in Argali. The traditional unit of area and water allocation in Majuwa is also the _maato muri_. Each farmer could readily report the number of _muri_ of water to which he was entitled. Since the water supply is so plentiful, diminishing the need for careful measurement and distribution of the water, this familiarity with one's allocation is likely the result of the fact that each year farmers are billed for the maintenance contract according to the amount of their water allocation.

[30] During the monsoon of 1983, there was a landslide that damaged the tunnel, and the members were called upon to work to reopen the canal.

Water Distribution. Water distribution for rice is by continuous flow. It is apportioned from the main canal into secondary channels by the use of saachos. Because of the abundant supply, distribution within the secondaries is generally done without precise measurement. Water is apportioned into field channels and fields by using stones and mud to adjust the size of outlets. Distribution for wheat is on demand with the order of rotation decided by the farmers wanting to irrigate on a given day.

Resource Mobilization. Cash to pay the maintenance contract is now the main resource mobilized by the organization. As mentioned above, assessments are based on the members' allocations of water. In 1982, the rate was Rs. 2 per muri. The special contracts for digging tunnels are paid for by the same method.

Decision Making. The major decision to be made by the organization is the amount of the maintenance contract. In theory, selection of the contractor is another decision. However, the same person has held the contract every year since the initiation of this method. The decisions are made at a meeting of all the members of the organization.

Conflict Management. As a result of the plentiful water supply, irrigation-related conflicts are rare. It was reported that prior to the tunnel construction in 1970, there had been some water stealing. Farmers caught stealing water were fined.

3.5.4 Organizational Structure

The Damgha Kulo irrigation organization exhibits considerably less structure than those studied in Argali and Chherlung. The hypothesis that will be developed in Chapter 5 is that this is primarily because far fewer resources need to be mobilized to acquire water in this system than in the Argali and Chherlung systems.

Officers/Functionaries. The only officer of the Damgha Kulo organization is the chairman. He is not paid for fulfilling this position but has been awarded the contract to maintain the system. He chairs the meetings of the organization, organizes all the maintenance work, collects the members' payments, and keeps a record of the payments. He serves for a year at a time and can be replaced if the members are dissatisfied with his performance or if he were to demand too high a payment. He has held the position since 1970.

Meetings. Annually, there are two regular meetings of the Damgha Kulo organization. At a meeting in November, the accounts from the previous year's contract are cleared and the amount of the next year's contract decided. There is also a meeting in April. At this time half of the contract payment is to have been raised, and accounts are reviewed. There may also be discussion about system operation in the upcoming monsoon season.

Records. The Damgha Kulo irrigation organization retains few written records. The only ones that were uncovered were a list of the member households, their water allocations, and an accounting of their payments for the current maintenance contract. These were all kept by the chairman.

3.6 Thambesi

3.6.1 Physical Setting and People

Thambesi is the site farthest from the research base in Argali and the one that stands out as the most different of the four. The water supply is much scarcer, the cropping pattern different, and, contrary to the other three, there are no Brahmins or Chhetris in the community. Both geographically and socially it could be termed the most remote of the four primary research sites.

Thambesi is located in Kothar Village Panchayat of Nawal Parasi District. It resides on a river terrace bounded by the Kali Gandaki river to the north and the Saune Khola stream to the west. The nearest market town is Narayanghar on the tarai, normally a 7- to 8-hour trek if one is not burdened with a heavy load. A trip to the district center of Parasi involves an additional two- to three-hour bus ride west on the Mahendra Rajmarg, the national east-west highway.

The irrigation system is in Ward 5 of the village panchayat. Half of the 55 households which are members of the system are located in this ward, while the remainder are scattered among the remaining eight wards. The all-household census numbered 219 households in the five wards nearest the irrigation system with a total population of 1482. Magars, a Tibeto-Burman people noted for their cooperative social interaction, are the dominant ethnic group in the locality, accounting for over 60 percent of the households.

Newars, with just over 10 percent of the households, are the next most numerous single ethnic group. The Newars of Thambesi are all engaged in farming, and some of the wealthiest households with the largest landholdings are Newars. They have learned to speak the Magar language--further indication of the dominance of the Magars--in addition to Nepali and no longer retain their Newari language. They reported that their ancestors moved to Thambesi from Lamjung District. The remaining households consist of Kumals and occupational castes (Damai, Kami, and Sarki).

Of the 300 hectares that make up the Thambesi river terrace, an estimated 210 are cultivated. Two irrigation systems, the Matillo Kulo (Upper Canal) and Tallo Kulo (Lower Canal), irrigate approximately 30 hectares of khet on the western side of the terrace. The Saune Khola stream is their source. Table 3.10 summarizes these two systems. A number of other small canals supplied by the Saune Khola and springs irrigate a total of just a few hectares on this western side of the terrace. To the east there is khet irrigated by a stream that completely dries up in the winter. The Thambesi area is pictured in Figure 3.4.

Table 3.10 The Thambesi Irrigation Systems

System	Command Area (ha)	Khet (ha)	Total Farmers	Constraint to Expansion
Tallo Kulo	50[a]	22.6	55	Water
Matillo Kulo	15[a]	8	28	Water

[a]Estimate from air photo.

3.6.2 Farming System

Cropping Pattern on Khet. The Saune Khola, which is the source of irrigation for the Thambesi farmers, has a lower volume of flow than the streams which supply irrigation in the other three sites. It has a small catchment area which is being rapidly deforested. Hillsides in the catchment area are cultivated using swidden technology. Due to the smallness of the watershed and the deforestation, the flow in the stream is very much dependent upon rainfall--swelling during a heavy rain but rapidly reducing to a low volume.

Only one crop per year, a monsoon rice crop, is grown on most of the khet. Most of the fields lie fallow the remainder of the year, and livestock are put out to graze on them. In the pre-monsoon season, rice is grown on a small fraction of the command area near the intake.

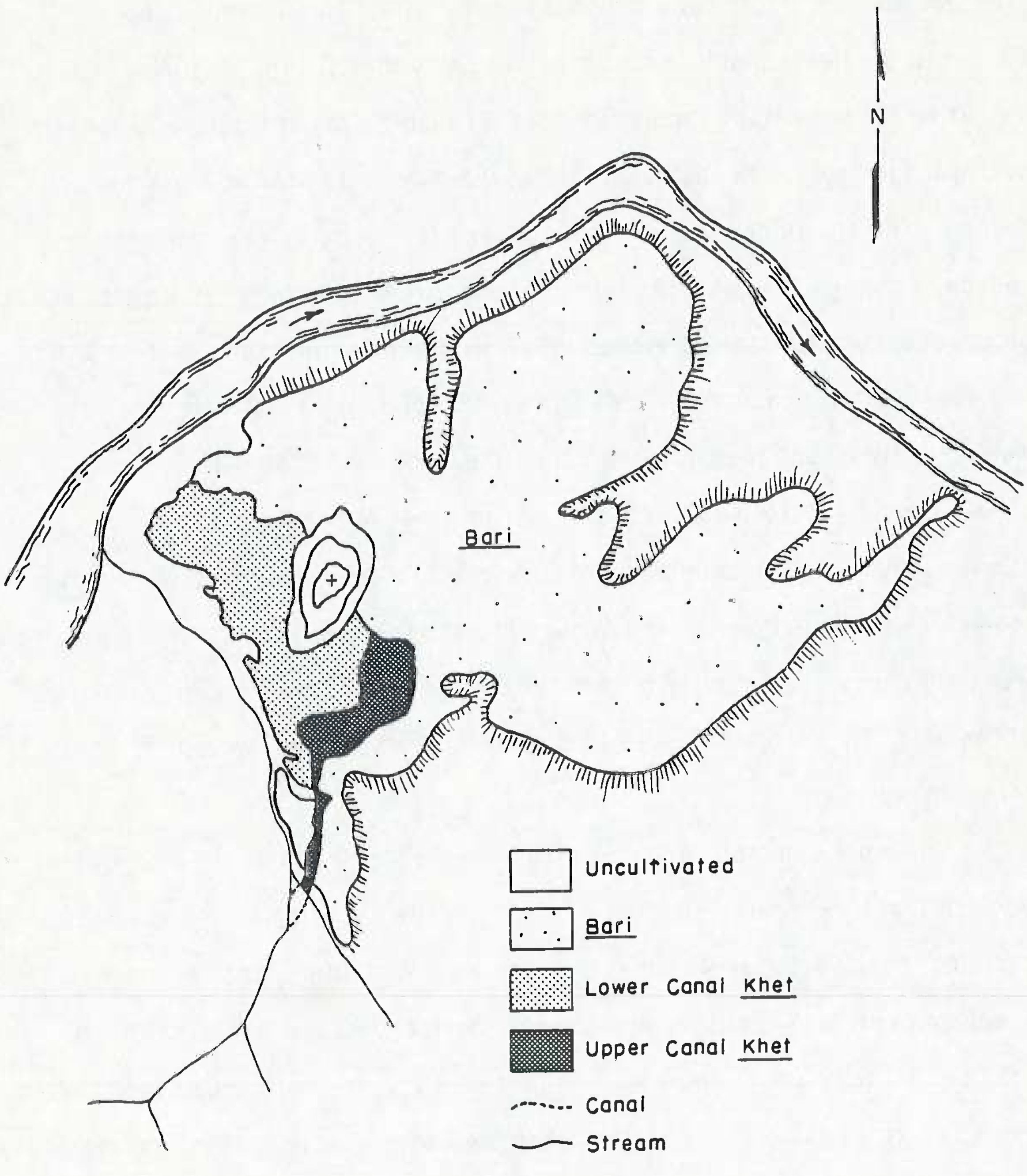

Figure 3.4 Thambesi Irrigation Systems and Land Types

Seedbeds for the monsoon rice crop are established in June. Because of the low base flow in the Saune Khola, the timing of seedbed preparation is dependent on early monsoon rains. In 1982, many farmers prepared their seedbeds on June 9 following a night of heavy rain. This downpour both saturated the fields and increased the supply in the stream, assuring irrigation for the established seedbeds. Transplanting of the rice is spread over a longer period in Thambesi than in the other sites for at least two reasons. First, since most of the fields are fallow in the pre-monsoon season, farmers are not waiting until the last minute to harvest a maize crop before transplanting the rice seedlings. Farmers begin transplanting one to two weeks earlier than in the other sites. Second, the relatively smaller water supply means that it takes more time to do land preparation--the supply cannot saturate as much of the area for land preparation simultaneously as the supply in the other sites does. In 1982, transplanting took place between June 30 and August 12, and the mean date of transplanting was July 20--a week earlier than in the other sites. The standard deviation of the date of transplanting was 10 days compared to 4 to 7 days in the other three sites.

The most common varieties planted were IR-20 and Jaya, both modern varieties with relatively short stalks. While the reason most often cited for planting these varieties was that they are higher yielding, the second most frequent reply was that they are drought-resistant and/or ripen early. It may be that they are higher yielding because they are not hurt as much by moisture stress late in the season when the water supply is low. Harvest was at the same time as in the other sites, between November 3 and 23 with a mean date of November 15.

No farmer in Thambesi applied commercial fertilizer to the monsoon rice crop. Leaves stripped from the asuro bush are placed in the seedbeds to improve the fertility. In the winter and spring while the fields are fallow and livestock allowed to graze in them, the animals are tethered in the field at night. Farmers systematically shift the tethering point around their fields so that manure will be deposited on all parts of their khet. The irrigation water also carries nutrients, especially the first flood waters of the season. These flood waters wash nutrients from the hillsides, where slash and burn cultivation is practiced, down into the irrigation system. A real effort is made to capture these first flood waters.

Rice yields, as measured by the sample crop cuts, were somewhat lower in Thambesi than in the other sites. The average of 59 sample crop cuts was 3.1 tons per hectare. Average yields were lower in Thambesi primarily because more of the fields suffered from moisture stress than in the other sites. Before the monsoon rice season, farmers said that the yields in the tail were considerably lower because the water was insufficient to serve this part of the system. The crop cut and moisture stress data confirmed their observation. Twenty-five plots were monitored for moisture stress, and nine of these were in the extreme tail of the system. Using the convention developed by Wickham (1972) for monitoring moisture stress in flooded rice by counting each day without standing water in the field, beginning with the fourth consecutive day, as one stress day, these nine fields had considerably higher stress-day counts than the others in the sample. For these nine fields, the count ranged from 26 to 41, while none of the others were over 21. Unfortunately, three of these which suffered high stress were harvested without samples being taken, but the average yield of the other six was only 1.6 tons/ha. The average yield of the other 16 sample plots in which stress was monitored was 3.4 tons.

Following the rice harvest, most of the khet fields in Thambesi lie fallow the rest of the year. Farmers maintained that there was not enough water in the stream to grow a winter wheat crop. However, comparison of the flow in the Saune Khola with the amount of water that farmers in Argali and Chherlung used to irrigate wheat indicated that wheat cultivation would be feasible. During the 1982-83 wheat season, the discharge in the systems in Argali and Chherlung averaged around one liter/sec/ha (Yoder, 1986). Measurement of the discharge of the Saune Khola revealed that there was at least 20 liters/sec discharge available in the stream for most of the season. Farmers may have perceived this as too little because their only experience with irrigation had been with flooded rice.

Several other reasons were given for not growing wheat. One was the problem of livestock. People are accustomed to grazing their animals on the khet during that season, and coordinated action would have to be taken to prevent the crop from being damaged by livestock. Also, seeds and fertilizer have to be purchased from the sajha, a day's trip from Thambesi. Some farmers lack the cash to purchase seed and the recommended fertilizer, and a loan for the wheat crop is perceived as both risky and difficult to arrange. One year in the 1970s, the sajha provided seed free of charge and said it would buy the wheat. Many of the farmers planted wheat, but then the sajha did not buy it. The farmers said the yield was very low. A final reason given for not growing wheat was that it is hard to digest when milled by hand. There was no mill in the vicinity of Thambesi until a water-turbine-powered mill was installed in 1982 in a village that is a one- to two-hours' walk to the west.

In the winter of 1981-82, as usual, no wheat was grown in Thambesi. However, in 1982-83, possibly as a result of repeated questioning as to why wheat was not grown,[31] fifteen farmers planted a total of about four hectares of wheat.[32] All but four of them applied some commercial fertilizer, but only five carried FYM to their fields. (The manure that is collected in the stables during the monsoon is reserved for the maize planted on the bari.) The mean planting date, December 27, was three weeks later than in the other sites, but harvest was at the same time, in mid-April.[33] The mean yield of the 19 sample crop cuts was 2.1 tons/ha. This compares not too unfavorably with the 2.5 yield measured in Argali and Chherlung and 2.2 in Majuwa, all places with much more experience in growing wheat.

The Thambesi farmers' wheat irrigation practices reflected their inexperience. Most irrigated their wheat five times, and one farmer did seven times. His was one of the lowest yields measured. Water was applied until it was standing in the field, and the farmers felt the soil should always be kept looking moist. In the sites with more experience irrigating wheat,

---

[31] It was said that the farmers wanted to show the researchers why they did not ordinarily grow winter wheat, i.e., that the water supply was too low. It seems doubtful that they would risk the investment for such a demonstration, but perhaps the questioning did stimulate an urge to try wheat again. The Agricultural Assistant, a local farmer with one month's training who is paid a nominal stipend to be the contact farmer for the extension service, met with the farmers and took orders for seed and fertilizer. Unfortunately, the sajha was not able to fill their order, and they ended up buying wheat of unknown quality in the market and planting it.

[32] This necessitated more control over the grazing livestock, and villagers were heard complaining about this.

[33] The later planting was probably a result of the difficulty the farmers had in getting seed. It may also reflect the fact that they were not going to plant a crop in the pre-monsoon season after wheat harvest and thus did not have to be sure it ripened as soon as possible. It did, however, mature at the same time as in the other sites. This supports the argument of farmers in Argali that it does not matter much when the wheat is planted; it will ripen at the same time anyway.

three applications were generally considered sufficient. The farming system is in transition in Thambesi, and as experience is gained, more area will likely be planted in wheat. (According to reports received from there, in the two winter seasons since the field research was conducted, wheat has been planted over a larger area.)

In the pre-monsoon season, rice was grown on less than one hectare at the very head of the Tallo Kulo command area. All the rice was the improved variety called Taichin. Of 17 crop cut samples taken, the mean yield was 2.8 tons/ha. These included some samples that were cut from sample farmers' fields not in the Tallo Kulo command area. Unlike the farmers in the other research sites, Thambesi farmers grew no pre-monsoon maize on the _khet_. Farmers with fields in the head of the system were able to take all of the water to irrigate rice in this season. Table 3.11 presents a summary of the estimated yields from the Tallo Kulo system.

Table 3.11 Sample Crop Cuts, Thambesi _Khet_

	Monsoon Rice	Wheat	Early Rice
Number cuttings	59	19	17
Planting date[a] - mean	20/7	27/12	3/4
Harvest date[a] - mean	15/11	16/4	13/7
Yield[b] - mean	3.1	2.1	2.8
minimum	0.7	0.9	1.4
maximum	5.2	3.5	4.3
s.d.[c]	0.9	0.7	0.9

[a](day/month) [b]tons/ha [c]standard deviation

Cropping Pattern on Unirrigated Bari. All 25 households in the sample grow maize as the primary crop on their _bari_ fields. The planting date depends on the rainfall, but it is usually between mid-April and mid-May. In

1982, half of the farmers in the sample planted upland rice on a portion of their bari in this season. Both maize and upland rice are harvested in late August or September. Sample crop cuts were not taken of these upland crops, but the farmers estimated their maize yield to be less than a ton per hectare.

Most of the bari is left fallow the rest of the year, but farmers grow several other crops on parts of it. All but two of the sample farmers grew black lentils, and only one did not grow some mustard. Over half grew some millet and a bean crop on part of their bari. All of these crops are planted in September following the maize harvest and harvested in late December or January.

Livestock. The average household in Thambesi raises more livestock than its counterparts in the other three sites, among which there is no significant difference in household livestock population. The average household livestock population in the four locations is compared in Table 3.12.

Table 3.12 Average Household Livestock Population

	Thambesi	Chherlung	Argali	Majuwa
Female Buffalo	2.2	2.5	2.7	2.5
Bullocks	2.9	1.0	1.5	1.4
Cows	5.4	0.8	1.0	1.3
Goats	9.5	1.9	1.8	2.1
Chickens	19.7	1.6	0.4	1.4
Pigs	1.9	0.3	0.0	0.0

Thambesi farmers are able to raise a larger number of animals because their cropping pattern is not nearly as intensive. For much of the year, they can allow the animals to graze on the fallow khet fields. Raising more livestock compensates somewhat for the less intensive cropping. Some are raised for sale, and Thambesi residents eat more meat than the high-caste Hindus in the other sites.

3.6.3 Irrigation Management Activities

Water Acquisition - Construction. In the same way that the different water supply, at least as perceived by the farmers, has resulted in a different cropping pattern on the Tallo Kulo's khet in Thambesi, the nature of the physical system for irrigation has contributed to the formation of an irrigation organization different from those in the other research sites. From the diversion structure on the Saune Khola to the first fields in the command area, the main canal is less than 100 meters long, and the total canal length is less than 1000 meters. Constructing the canal did not require the major investment that it did in the other locations. Very little is known about the construction--it was before the lifetime of any residents and not notable enough that any commonly known oral tradition was uncovered. One 70-year-old informant thought that it was built six generations ago and that the construction took only three months. This is plausible given the length of the canal.

Another indication of the relative insignificance of the canal structure can be deduced from the name of the system and organization. In the other locations, to identify an irrigation organization and/or system, the people refer to the canal which serves it, i.e., the Raj Kulo (Royal Canal) system in Argali and the Thulo Kulo (Large Canal) system in Chherlung. Thambesi farmers, however, identify the two irrigation systems in terms of the fields they irrigate. They refer to the Tallo Kuloko Phant and the Matillo Kuloko Phant, i.e., the fields of the lower canal and the fields of the upper canal.

The elderly informant guessed that the size of the area irrigated had been increased by about 100 maato muri since the original construction. Because of the uncertainty of the size of a maato muri, one does not know how much expansion this represents. If a maato muri in Thambesi equals about one-eightieth of a hectare [as Regmi (1978) said had been established in 1907], then the expansion would have been only 1.25 hectares.

Water Acquisition - Maintenance. Maintenance of the canal is not the dominant activity that it is in many of the irrigation systems in the hills of Nepal. Routine maintenance, including repair of the intake and cleaning of the canal, is done in mid-July. This is said to take only a half day's work by the members and can, thus, be done later than in the other systems where it requires several weeks. After each heavy rain, the stone and brush diversion must be repaired, but this can usually be done by a half dozen farmers in a few hours.

The short main canal runs along a stable hillside on which there is no danger of landslides, a primary cause of maintenance problems in many systems. This reduces the amount of emergency maintenance required during the monsoon season, and daily patrolling of the canal as in Argali and Chherlung is not necessary. If farmers observe a reduction or interruption of the supply, it does not take long for them to investigate and repair the problem. In Chapter 5 it will be argued that the very low maintenance requirement of the Tallo Kulo system accounts in large measure for the paucity of organizational structure found in this system.

Water Allocation. In all of the irrigation systems studied in Argali, Chherlung, and Majuwa, the amount of each farmer's allocation of water was explicitly defined. Each of the seven irrigation organizations maintained a list of the members along with the amount of their water allocation, either in muris or shares. This allocation is a record of the proportion of the system's supply that a member is entitled to as well as the accounting unit by which resources are mobilized. Nothing of this sort was found in Thambesi. There was no list of the members' water allocation. Equally revealing was the fact that sample farmers could not respond in a meaningful way when asked the amount of their water allocation. Under some prodding by the enumerators, some of them replied with the area of their field. The figure reported was in ropanis,[34] the unit of area used in the very recent cadastral survey done by the government. Maato muri is the traditional unit of area in the hills, and if there had been an explicit water allocation based on the land area, it would have been established long ago and would likely still be denominated in muris as it is in Argali and Majuwa.

It was said that allocation was in proportion to the area irrigated, but there was no attempt to designate the allocation to which each field was entitled. Analysis of the pattern of water distribution suggests that there might be a different priority of rights within the system, although no explicit evidence for this was uncovered. Thambesi is the only system studied where, in the pre-monsoon season, all of the water is used by a few farmers with land at the very head of the system to grow rice, and most of the command area remains fallow. In the other systems, all of the member farmers share the limited pre-monsoon supply and in most cases plant the entire command area in maize.

During most of the monsoon season, distribution is by rotation, and the system is divided into four different units. A map showing the rotational units is presented in Figure 3.5. As can be seen, all of the units include some fields in the head of the command area. Units 2, 3, and 4 extend to the

---

[34]There are approximately 19.7 ropanis in a hectare.

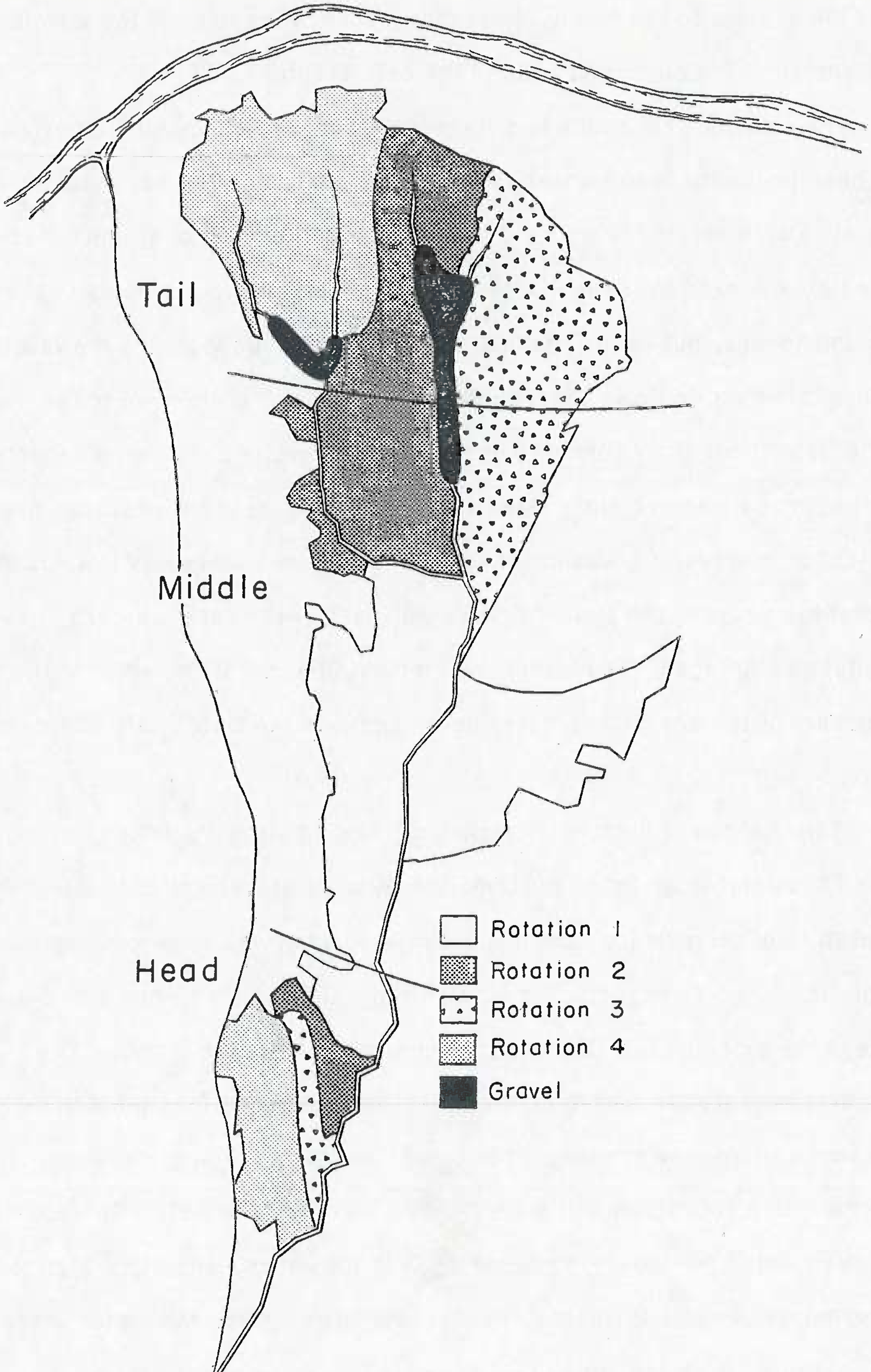

Figure 3.5 Thambesi Tallo Kulo Irrigation System

tail of the system to the north, while unit 1 covers the area in the middle and an extension of the command area to the east around a hill.

The rotation procedure is different than that practiced in both Argali and Chherlung. There the water flows continuously into the secondary channels and is rotated from field to field within the rotational units made up of the fields served by a secondary. In Thambesi, the total supply is rotated from unit to unit, but within the unit it flows continuously during the length of the turn. The water flows through the rotational unit from head to tail, and all the fields have their turnouts open to receive water. Farmers reported that the turnouts are roughly sized so that farmers receive what they are entitled to; however, it was observed that when the supply was low, as it was much of the season, the fields in the upper part of the rotation were definitely advantaged. They were well irrigated every turn, while in the latter part of the season the water never reached the fields in the extreme tail.

This method of rotation assigns, at least implicitly, priority of rights to the fields higher up in the system. No explicit statement of this hierarchy of water rights was heard, but if the irrigated area was expanded somewhat at one time, as was reported, most likely the fields which were added were those in the extreme tail that experience the most severe stress. The system is operated in such a fashion that the tail end suffers when the supply is scarce rather than spreading the stress out over the whole system. If the water within a rotational unit were rotated from field to field with each field receiving water for a period proportional to its water allocation, then there would not be as much difference in observed stress, and the yields in the tail end would not be significantly lower than in the rest of the system.

In conclusion to this discussion, it appears that in Thambesi there may be three different areas with three different priorities of rights. The head area has the highest priority and can take all of the water in the pre-monsoon to grow rice. The middle section has an equal priority of right to water in the monsoon season, and the extreme tail has the lowest priority. It will be argued later that the organization can only function in this way because, unlike the systems in Argali and Chherlung, very little labor is required to maintain the system for acquisition of water.

Water Distribution. The water distribution procedure was essentially described in the foregoing section. What was not mentioned was that fact that there are four different rotation schedules depending on the amount of the supply in the stream. If there is plenty of water, half of the system receives water for 12 hours, and then the other half is supplied for 12 hours. Under the next schedule, each of the four rotation units receives water for 24 hours and then goes 72 hours without water. The third schedule provides water to each rotation unit for 36 hours, and each must wait 108 hours until it is supplied again. When the supply is at its scarcest, each unit receives water for two days out of eight.

When the water is exceptionally scarce, the rotation unit may be further subdivided as happened in the monsoon season of 1982. The tail portion of rotation unit four was split into two parts when the fourth rotation schedule was initiated. One part received all the water on one day of the two-day turn, and the other part took it all on the following day. This way the volume of water on a given turn was covering a smaller area enabling it to reach fields farther toward the tail in the unit, but each field in the unit received water for a shorter time. If the rotation unit had not been divided in this way, the number of fields that essentially received no irrigation late in the season would have been higher.

It was observed that even though fields in the head were in rotation units with fields in the tail, the head received water more frequently than the tail portion of the unit. Water flow data showed that late in the season, when the majority of the system was rotating at the fourth level, the fields in the head were at level two.[35] This, coupled with the fact that the head area of the system was allowed to take all the water in the system for irrigating pre-monsoon rice, again supports the supposition that the head has a higher priority water allocation than the rest of the system. Alternatively, it would be possible that what was observed was systematic stealing of water by the locationally advantaged farmers in the head.

Resource Mobilization. The mobilization of resources for water acquisition in Thambesi is not the critical activity that it is in Argali and Chherlung. Significant amounts of labor are not required for the annual routine maintenance or for emergency maintenance during the monsoon season. Routine maintenance of the system to prepare for the monsoon season takes the members less than a day. All members are supposed to work on this day as well as on any other day that there is maintenance activity. In practice, when a reduction in the supply indicates that the diversion structure needs repair, farmers who are available go and do the work in a few hours, and no effort is made to call all the members. Sample

[35]Water was recorded in the secondary serving the head area of rotation unit four every fourth day, i.e., the level two rotation schedule. The V-weir which measured the flow to half of the tail portion of the fourth rotation unit had water flowing over it only every eighth day. The tail section was rotating at level four(two days on and six days off), and within the unit, half of the area received water for the first day and the other half for the second day of the turn. [See Yoder (1986), Chapter 8, for the water measurement data.]

farmers, on the average, reported that they had worked on the system seven times during the monsoon season.

Decision Making. Formal decision-making procedures, such as regular meetings of the organization and committees as were seen in Argali and Chherlung, were not found to be part of Thambesi's Tallo Kulo organization. It was said that anyone could call for a meeting if he felt something should be discussed by the organization, but this happens infrequently. A few of the wealthier farmers were said to dominate the discussion in the occasional meetings. Farmers are frequently in their fields overseeing the distribution of water according to the rotation. At these times, as it is perceived necessary, decisions are made to change the rotational pattern.

Conflict Management. It was reported that because of the relative scarcity, there is stealing of water. This stealing was said to take place between individual farmers as well as rotational units. No formal grievance procedure exists, nor are there formal sanctions for stealing. Farmers rebuke anyone caught stealing their water and attempt to steal in return.

Uncontrolled grazing is another source of conflict. When animals are caught by a farmer in his field, khet or bari, a group of farmers will estimate the damage done, and the owner of the animals must pay the offended farmer an equivalent amount of rice or maize.

3.6.4 Organizational Structure

The organization of Thambesi's Tallo Kulo irrigation system is far less structured than any of the systems studied in Argali and Chherlung. The Damgha Kulo organization in Majuwa, while exhibiting less structure than those in Argali and Chherlung, is also more structured than the Tallo Kulo organization in Thambesi.

Officers/Functionaries. There are no recognized officers or functionaries in the Tallo Kulo organization. At the time when there was an appointed local tax collector (jimmawal), he was said to have acted as a leader of the irrigation organization as well. With the abolition of that position, there has not been any formal leadership position established. It was observed that the wealthiest Newari farmer exercised considerable influence in matters related to the operation of the system. In addition, the ward chairman, a local political leader (at that time a Magar), kept a list of the members of the organization, suggesting that he also provided some leadership.

Meetings. The organization holds no regularly scheduled meetings, and unscheduled meetings are infrequent.

Records. With the exception of the membership list, the organization maintains no written records.

The Tallo Kulo irrigation system in Thambesi differs strikingly from the ones which were studied in Argali, Chherlung, and Majuwa in several ways:

1. It has the lowest water supply relative to the area that is irrigated, among the eight systems, and requires the highest degree of management for water distribution.

2. It exhibits the most amount of disparity between the head and tail sections of the system with regards to yields and moisture stress.

3. It requires the mobilization of the least amount of resources for water acquisition, i.e., for maintenance of the system.

4. Individual members' water allocation is much less explicitly defined than in the other systems.

5. The organization is the least structured of the eight organizations.

In Chapter 5 it will be argued that there is a relationship among the last four points, and that 2, 4, and 5 are, at least in part, a direct result of 3.

3.7 Adaptation as Population Pressure Increases

To conclude this description of the communities and irrigation systems studied, a comparison of some of the population and land-use statistics will be presented to suggest some of the dynamics of their adaptation to increasing population pressure. The population in Nepal has been growing rapidly over the past several decades, increasing the demand for food production and the pressure on the agricultural resource base. The communities which were studied have adjusted to this population pressure through a variety of adaptive responses. Irrigation development and management, which have been shown to enable extremely intensive agricultural production, are important elements in this adaptive process, but not the only ones. The water supply available in the different communities has been seen to present different possibilities and constraints on how irrigation can be used to increase the agricultural production in specific areas. Table 3.13 presents official population census data for the panchayats in which the four primary research sites are located.

Because of the uncertainty as to whether the area included in Kothar Panchayat, where Thambesi is located, was the same in 1971 and 1981, it is not possible to say whether these figures do represent depopulation as a result of out-migration. The figures for the other panchayats reveal a growing population, part of a trend that began decades earlier.

Table 3.13 Population Census Data

Research Site	Panchayat	1971	1981	Percent Increase
Thambesi	Kothar[a]	4011	3681	-8
Chherlung	Bougha Gumha	2565	2881	12
Argali	Argali/Kheha[b]	4554	5601	23
Majuwa	Rupakot	2629	3001	14

[a]The boundaries of Kothar Panchayat may have been shifted some between the two census. Since the census of 1981, the panchayat has been divided into two, Kothar and Ratanpur.
[b]In 1971 Argali and Kheha were two separate panchayats while in 1981 they had been joined into one. Since 1981 they have been separated again.

Source: Population Census, Central Bureau of Statistics, National Planning Commission Secretariat, Kathmandu.

An all-household census was conducted by the researchers in three of the research sites in 1983--Thambesi, Chherlung, and Argali. This census did not cover the entire panchayats, only the wards that were in the immediate vicinity of the river terraces on which the irrigation systems were located.[36] Table 3.14 presents the results of the household census as well as the data on the area that is cultivated in the three sites.

[36]When analyzing the population that is supported by agricultural production from a given cultivated area such as a river terrace, it is very difficult to determine exactly what population should be considered. The household census of the wards on the river terraces, in all probability underestimates the population and, thus, gives an underestimate of man-land ratios. Some people who are supported by the production from the irrigation systems live on the hills bordering the terrace. There is less of this in Chherlung and probably more in Thambesi than Argali.

Table 3.14 Household Census and Land Area Data

	Argali	Chherlung	Thambesi
Population	2690	1278	1482
Land (ha):			
Khet	88	61	30
Irrigated Bari	60	13	0
Unirrigated Bari	65	9	180
Total	213	83	210
Man-Land Ratio	12.6	15.4	7.1

The man-land ratios in Argali and Chherlung are fairly similar while Thambesi's is considerably lower. With the triple-cropping of the khet and double cropping of the irrigated bari in Argali and Chherlung, the cultivated land is much more productive than in Thambesi. In Table 3.15, the man-land ratios comparing the population with the area of "cropped-land" were calculated. In determining the area of "cropped land," the actual area is multiplied by the cropping intensity, i.e., the number of times the land is cropped in a year.

Table 3.15 Population and "Cropped Land"

	Argali	Chherlung	Thambesi
Cropped Land (ha):			
Khet	88 X 3 = 264	61 X 3 = 183	30 X 1 = 30
Irrigated Bari	60 X 2 = 120	13 X 2 = 26	0
Unirrigated Bari	65 X 1 = 65	9 X 1 = 9	180 X 1 = 180
Total	449	218	210
Man-Cropped Land Ratio	6.0	5.9	7.1

The ratio of population to cropped land (area adjusted for multi-cropping) is remarkably similar across the three sites, suggesting that they are all in some type of dynamic equilibrium. While one must refrain from reading too much into these numbers, it makes sense that the ratio is somewhat higher in Thambesi. Farmers in Thambesi raise considerably more livestock than those in the other sites as was shown in Table 3.12. These livestock graze on both the khet and bari when there is no crop in the fields.

Using the yield figures estimated from the crop cuts in the different sites, the annual grain production per person is presented in Table 3.16. No crop cuts were taken from the bari fields in Chherlung nor Thambesi. The Argali and Chherlung farming systems are extremely similar, so the yields from bari measured in Argali were assumed for Chherlung as well. It was assumed that the yield of maize from the unirrigated bari in Thambesi was less than in Argali and Chherlung. The farmers' estimate of the yield was very low--under one ton per hectare. The maize yields were probably not that low, but were likely lower than in those two sites. Thambesi farmers do not use any commercial fertilizer on the bari and do not compost the manure and carry it to the fields to the extent that this is done in Argali and Chherlung.[37] A yield of 2.5 tons/ha for maize grown on unirrigated bari in Thambesi was assumed.

[37]The Thambesi farmers' estimate of the rice yields on the khet was considerably lower than that given by the crop-cut data.

Table 3.16 Grain Production Per Capita

	Argali	Chherlung	Thambesi
Khet	88 X 7.5[a] = 660	61 X 8.4[a] = 512	30 X 3.1[a] = 93
Irrigated Bari	60 X 6.8 = 408	13 X 6.8 = 88	0
Unirrigated Bari	65 X 4.4 = 286	9 X 4.4 = 40	180 X 2.5 = 450
Total	1354	644	543
Annual Production/Person (tons)	.50	.50	.37

[a]Tons of grain/ha/year

3.7.1 Argali, Chherlung, and Majuwa - Intensive Agriculture

Argali, Chherlung, and Majuwa have been responding to a growing population and an increasing demand for food for many years. Actions have been taken to increase the supply of food as well as to limit the demand. Changes have been made in the farming systems to intensify production. One of the first steps made to increase production was the original construction of an irrigation system which happened centuries ago in Argali and only 50 years ago in Chherlung. Prior to the development of irrigation, the main crops grown were likely upland rice and millet. Irrigation systems were originally built for the cultivation of flooded rice during the monsoon season. Irrigation made food production more secure and enabled cultivation of the preferred grain. For some time after development of a system, at least the in older ones, rice was the only irrigated crop. This was the only crop with which people had experience growing under irrigated conditions. As is still the case in Thambesi, animals were pastured in the khet field after the monsoon rice crop had been harvested.

Fifty or more years ago, farmers began growing maize on the khet fields. This involved a major change in the farming system because the livestock could no longer be put out to graze freely on the khet fields but had to be taken farther away to jungle areas or stall-fed, requiring considerable labor for fodder gathering. In Thambesi, where in 1981 the practice was still to grow only a monsoon rice crop on the khet, some of the farmers decided to try planting wheat in the winter of 1982. There was grumbling and resistance to it because it meant that the livestock would have to be tended much more carefully to prevent them from damaging the wheat. Before the season there was some talk of requiring everyone to plant a crop during the winter so that all would have an equal interest in protecting the crop from livestock. As can be seen, intensifying the cropping by introducing a second irrigated crop means also intensifying the effort in livestock production.

The third crop to be introduced in the cropping pattern was wheat. It was reported in Argali that for some time people did not grow three crops on the khet but planted either wheat or maize. Now, nearly everyone grows all three crops. Wheat yields were said to have increased substantially about 15 years ago after farmers began to invest greater effort in land preparation.

In Argali an element of the response to the demand for more food has been the irrigation of bari fields in the winter and spring. While access to irrigation during the monsoon has been tightly controlled, anyone who wants water can take it to irrigate wheat and for planting maize. Irrigating bari must have been an entirely new technology as irrigation systems had always been designed for irrigation of flooded rice. The production achieved from the irrigated bari suggests that the development of irrigation systems exclusively for irrigation of upland crops in areas with limited water supplies could have very high pay-offs. It requires a change in the traditional thinking about irrigation in Nepal as primarily for lowland rice.

In Argali, Chherlung, and Majuwa, the irrigation organizations have made improvements almost continuously in their irrigation systems to increase the volume of water which is delivered as well as the reliability of the supply. This has allowed for the increase in the number of crops that are grown as well as an expansion of the area that is irrigated. The analysis is Chapter 7 will show that just how far the irrigated area is expanded depends a great deal on the type of principle of water allocation that is operative in a location.

As these changes in the farming and irrigation systems have been taking place over the years, the communities have also been adapting in other ways to the increasing population pressure. Some of these adjustments involve actions which reduce the demand for food from local production. Many households in Argali, Chherlung, and Majuwa have family members working in India, some of whom send or, more often, once a year bring remittances back which contribute to the household income. By being away, they also reduce the local demand for food. Our neighbor family in Argali is a good illustration of what is happening. The father, who is approximately 70 years old, worked for some years in Burma. Between his inheritance and the land purchased with his earnings, he had enough land to live relatively well and was able to build a better-than-average house. But his land is not sufficient for his four sons to all support their households solely by farming. One son has left permanently and works in Assam, India, as a police officer. Another son works in India and only comes back to see his wife and children once a year. His wife farms his share of the land. A third son teaches in the local school to earn income to supplement the production from his portion of the family land. The fourth son, his wife, and children live at home with the parents and help to farm the land that the father still controls. There is no way that the land that supported the father reasonably well is anywhere near sufficient for his four sons.

At the same time that people are leaving Argali, either permanently or for temporary employment, its relative prosperity and strategic location does attract some in-migration. Of the three sites in which the all-household census was taken, Argali had the highest number of landless. Because it is on such a major transportation route, people are able to find work such as portering. There is also more construction work available in Argali than in poorer communities.

When one looks to the future, it is difficult to say what adaptions can be made to increase food production in Argali, Chherlung, and Majuwa. In both Argali and Chherlung there is still some bari that could be converted to khet and a monsoon rice crop added to the cropping pattern.[38] Rates of fertilizer use could be increased. It is questionable whether, with the extremely high applications of irrigation water to the monsoon rice, more fertilizer will result in higher rice yields. Most farmers in Argali are already applying fertilizer to the rice crop while few in Chherlung do and none in Majuwa are. Yet the sample crop cuts from both Majuwa and Chherlung had slightly higher average yields than from Argali. The high water application rate may leach out the fertilizer before it can benefit the rice. Perhaps lower applications of water would result in a higher response to the application of fertilizer. This is an area for research.

Farmers in these three locations have not been satisfied with the improved varieties of rice that they have tried, and the great majority continue to grow traditional varieties. More work on developing and

[38] It will be argued later that this will not happen in Argali unless there is a change in the principle of allocation to provide incentives and a mechanism for expansion of the area irrigated.

promoting fertilizer-responsive varities may have payoffs, but the impact of the high water application rates with high rates of seepage and percolation needs to be studied before claims are made for what improved varieties with higher rates of fertilizer can produce.

Two varietal improvements that farmers in these very intensive systems would almost certainly adopt are a shorter-season maize variety and a wheat variety that would ripen earlier. They have expressed the desire for such a maize variety--in fact asked us to bring seeds for one called Arun. Maize appears to be the crop that suffers in the intense, triple-crop rotation. It is harvested before it is mature so that the monsoon rice can be planted. If the wheat would ripen earlier, the maize could then be planted sooner and would be more mature when it is harvested. The wheat ripens at approximately the same time in April regardless of whether it is planted in early December or several weeks later, so there appears to be some "slack in the system" between rice harvest and wheat planting.

3.7.2 Thambesi - Extensive Agricultural Production

The man-land ratio, cropping intensity, and livestock population show Thambesi to be at a different stage of evolution than the other three sites. The water supply is limiting, but it is not the sole reason that the farmers there grow essentially only one crop on the khet. There is sufficient water to grow a wheat crop in the winter, and maize could be planted over most of the area in the pre-monsoon season.[39] Instead, livestock graze on most of the khet with the exception of less than one hectare at the head of the system

[39]The main reason given for not growing winter wheat was that the water supply was too scarce. Although measurement of the supply showed there to be sufficient water to grow wheat over the entire khet area plus some, the farmers' perceptions of the amount of water needed may have been based on their experience with irrigating rice. There would certainly not be enough water to irrigate the wheat like rice is irrigated.

where a pre-monsoon rice crop is grown. As Table 3.12 demonstrated, raising more livestock is one way by which farmers in Thambesi adapt to the presssure for more food production.

This is the only area where we heard reports of people digging up roots from the jungle for food. Some people grow ginger which they take to market in the _tarai_. More of the sample households had borrowed to meet their consumption needs than in the other sites. Oddly, fewer households in Thambesi had members working in India than in the other sites where it was common; no sample household reported receiving remittances. However, since some of the Magars have served in the Indian army, 20 percent of the households reported receiving pensions. Only 16 percent reported a household member with a regular income-earning job, compared to about 50 percent in the other sites. Thambesi residents do go to the _tarai_ to work during peak labor periods in the _tarai_ agricultural cycle, the only site where this was reported.

Thambesi appears to be in a stage of transition. The Thambesi farmers are the only ones of the four sites who have adopted improved rice varieties. Their chief reason for doing so was that the new varieties were less affected by moisture stress. Perhaps, also, short-stem varieties are more acceptable in Thambesi because the straw is not as important as fodder since the livestock can graze. One would predict the livestock population to drop as cropping is intensified. In the winter of 1982-83, some farmers grew wheat on a portion of their _khet_, and the amount of wheat grown was reported to have increased in the past two winters. This means more effort will have to go into (1) taking animals farther away to graze and watching them to keep them from going into the cropped fields and/or (2) gathering fodder to stall-feed them. If it evolves into triple cropping, which seems possible on the area that is currently being irrigated, the livestock population would most likely drop significantly. It may not be reduced to the level it is in the other sites for several reasons. There is more land on the river terrace at Thambesi that will probably never be irrigated and, thus, not cropped intensively, leaving more grazing land.[40] The people of Thambesi are accustomed to more meat in their diets and will eat pork which the Brahmins and Chhetries in the other sites will not. If Thambesi is monitored over the coming years, it should be possible to observe the process of intensification to a three-crop cycle like has happened in the other sites over the past 50 or more years.

This chapter has provided a detailed description of the farmer irrigation organizations in the four primary research sites and the agricultural production made possible by the irrigation systems. The remainder of the dissertation will analyze: (1) the way in which management is intensified in response to the relative water supply, (2) the relationship of (a) relative water supply, and (b) resource mobilization requirements, to the structure of the organizations, and (3) the impact of the principle of water allocation on the efficiency and equity of irrigation resource use.

[40]Thambesis residents do know of another stream quite a distance away that might be developed for irrigation which would result in more area being irrigated. We did not investigate the feasibility of developing that source.

CHAPTER 4: MANAGEMENT INTENSITY:
A FUNCTION OF THE WATER SUPPLY?

One of the primary objectives of this research was to analyze the intensity of management in a number of farmer-managed irrigation systems in the hills of Nepal under different environmental conditions. Concern for better irrigation systems management has increased throughout the developing countries over at least the last 10 to 15 years. Observation of many of the systems inaugerated in the past several decades has led to a growing realization that the construction of the physical structures of an irrigation system does not insure desired performance.[1] Appropriate management is a necessary complement to the physical components of the system to enable achievement of the desired production from irrigated agriculture.

Efforts to improve the management of government irrigation systems usually include (1) extension of the canal distribution system further into the farming area, often with the intention of having field channels serve each plot individually, (2) changes in the delivery system, frequently incorporating plans for detailed rotation of the water, and (3) formation of water-user organizations (Levine, 1979). These modifications represent major increases in the intensity of management and changes in the mix of the physical and organizational components of that management. Yet there are uncertainties about the conditions under which any of the above changes are

---

[1]Evaluations of the irrigation systems constructed in Nepal in the last three decades have been extremely critical of their performance (Water and Energy Commission, 1981). The criticism has focused primarily on the poor management of the systems.

appropriate and about the effects of different intensities of management on system performance.

Farmer-managed systems, which have developed over a relatively long period of time in response to local environmental conditions and which tend to depend more on the nonphysical managerial inputs (software) than on the physical infrastructure (hardware), provide a rich sample of systems for analyzing management intensity.[2] Different farmer-managed systems incorporate some or all of the above-mentioned elements of increased management intensity. In Nepal, many of them have field channels serving each plot. Those with relatively scarce water supplies practice rotational distribution. Almost by definition, they have water-user organizations, but the structure of these was observed to vary considerably. It was expected that management intensity would vary among the systems studied, and that the structure of the management organizations would vary correspondingly. While there are a number of factors that may contribute to the intensity of management, it was hypothesized that management intensity would be clearly related to the water supply and that the two would be inversely correlated.

4.1 Theoretical Background

According to conventional economic theory of value, the relative scarcity of desired resources and commodities is a primary factor affecting differences in relative values. The oft-cited example compares the price of diamonds with that of water. Water, which is essential for all forms of life, is also an abundant resource in many parts of the world and, hence, is often available free of charge. Diamonds, on the other hand, are not vital to the

[2]See Levine (1979) for a discussion of the use of "hardware" and "software" in irrigation management.

sustenance of life, but because of their scarcity and the fact that they are considered beautiful, they command a very high price.

Similarly, a factor of production will be valued higher in a situation where it is scarce relative to the other factors than one in which it is abundant. Economically efficient production processes develop which maximize returns to the scarce resource. Pachico (1979) has shown this to be the case for farmers in Nepal. Farmers with large land holdings who produce for the market and must hire labor chose crop varities which maximized returns to cash inputs. Those with small holdings and higher household labor/land ratios selected varieties to maximize returns to their relatively scarce land.

In the western part of the United States, water is scarcer relative to land than it is in the eastern part of the country. Consequently it has a higher value in the West than in the East. Technologies and institutions which have developed in the two parts of the country reflect these differences in the value of water.[3] Because of its relative scarcity, the marginal value of adding water to the agricultural production process is higher in the West. Likewise, investments in irrigation systems in the West are profitable because of the higher value of marginal product from additional water, whereas they would not be in the East.

Not only do investments <u>to develop</u> irrigation respond to the relative scarcity and, therefore, value of water, the same is true of the investments <u>to manage</u> the water. <u>Ceteris paribus</u>, in a situation where water is scarce, more effort will be invested to increase the efficiency of water use than in a situation where it is abundant. This investment may take the form of more

[3] In Chapter 6, the difference in the institution of water rights in the two regions will be presented.

technically efficient physical structures such as permanent diversion structures, lined conveyance and distributary channels, and adjustable gates. If capital is scarce relative to labor, as is usually the case in the rural areas of less developed countries, the investment may be in more labor-intensive water management such as a rapid response to any maintenance needs and distribution by rotation instead of continuous-flow. In most irrigation bureaucracies, there is a tendency toward more capital-intensive investments because of a number of factors including (1) a distortion of the relative prices of capital and labor due to the availability of capital from donors, and (2) the engineers' bias towards construction and technical solutions as a result of their conventional engineering training.

Levine (1977) maintains that management and water are to some degree substitutable and has hypothesized that the management intensity would be inversely correlated with the water supply as shown in Figure 4.1. If the water supply of an irrigation system is scarce relative to the land that could be irrigated by it, one would expect to see more management effort employed to utilize the available water efficiently and equitably. A system with an abundant supply of water relative to the irrigable land area could afford to operate with a lower technical efficiency of water use, and one would expect to see less intensive management in such systems.

Levine (1977) analyzes data from several countries of Southeast Asia to demonstrate the trade-off between water and management. Figure 4.2 presents typical amounts of seasonal water requirements at the turnouts for rice taken from some of these countries which have a similar general monsoon climate.

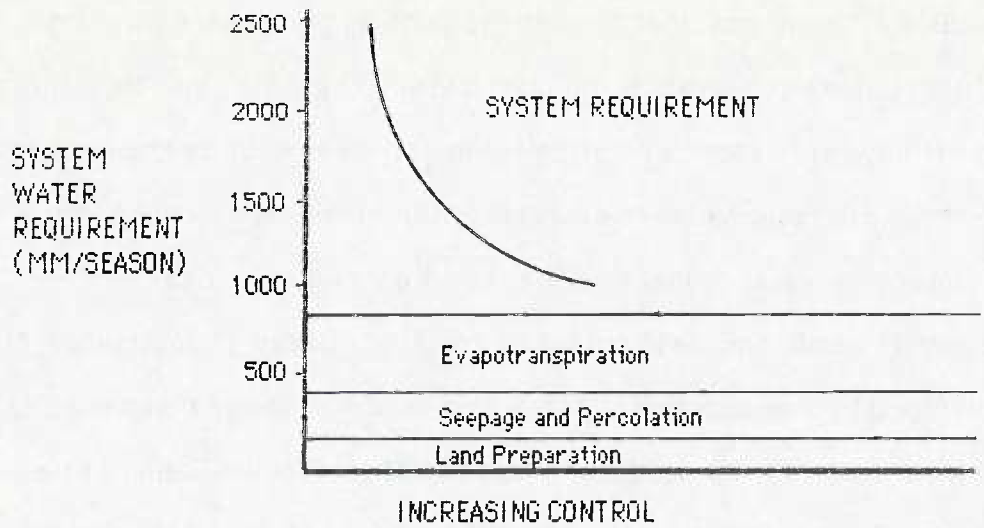

Figure 4.1 The irrigation water requirement for lowland rice as affected by the level of control inputs.

Source: Levine, 1977

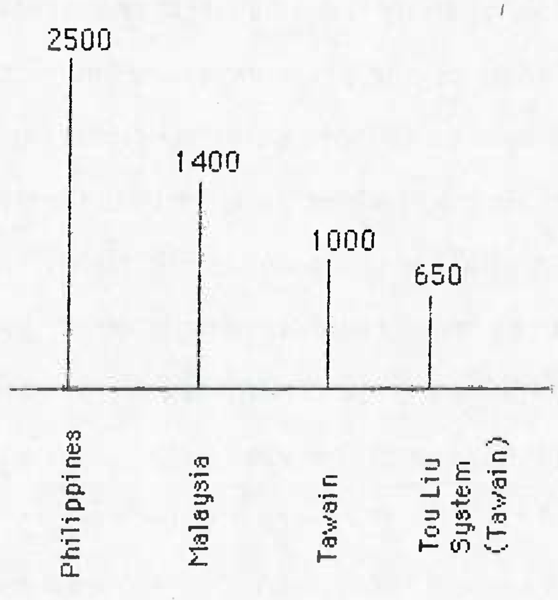

Figure 4.2 Typical irrigation system water requirements (mm/season).

Source: Levine, 1977

Among these countries, system water-use efficiencies vary from less than 25 percent to over 90 percent. The management input, as well as the investment in physical structures for water distribution, has been quite different among these countries, especially prior to the early 70s when the data in Figure 4.2 were compiled, and these differences affect the degree of water control that is achieved. Irrigation in the Philippines was by continuous-flow distribution; there were few effective controls and essentially no measuring devices in the distribution channels and turnouts; system maintenance was at a low level; system operating control was exercised only 8 hours per day, 5 days per week; and farmer cooperation in water distribution was variable and frequently of a low order. In contrast, irrigation systems in Taiwan distributed water by rotation in accordance with a specified plan within 50-hectare units; many of the distribution channels were concrete-lined; control gates and Parshall flumes for controlling and measuring the discharge were installed at each 50-hectare turnout; there was an extensive system of farm ditches; and on-farm water distribution was handled on a 24-hour basis. At an intermediate level were Malaysian systems with distribution by continuous flow; centralized and effective control within the primary and secondary distribution channels; water policy specified by ordinance each year; turnouts serving relatively large farming areas; few farm ditches; and distribution beyond the canal system in the hands of the farmers (Levine, 1977).

The disparity in management intensity and water-use efficiency can be partially explained by differences in factor endowments and the substitutability of water for other resources in more limited supply. Until recently, the Philippines was able to increase agricultural output by bringing uncultivated land under production and had water supplies that were relatively easy to develop. Available rice varieties had fairly low yield potentials, and governmental and farm incomes were relatively low. The investment necessary to use water more efficiently, in technical terms, was not considered justified, i.e., the value of marginal product of irrigation water was relatively low. The situation in the Philippines has changed with the introduction of rice varieties with high yield potential, the decreased availability of new land for cultivation, and the increased cost of developing new water sources. There is now more interest on the part of both farmers and the government in more efficient use of water through increased management input.

Taiwan's high water-use efficiency has been induced by a different set of resource endowments. Conditions favoring investment to achieve high water-use efficiencies have existed for over 50 years. These include: limited agricultural land, relatively high-yielding varieties of rice, and a scarcity of new, easily developed water sources. These factors result in a value on efficient water use that is high relative to the costs of achieving this efficiency (Levine, 1977).

With an argument similar to the theory of induced innovation, Levine (1981) has proposed that irrigation systems (and a country's irrigation sector) evolve through three different phases. Over a period of time, systems will be operated differently in response to changes in the combination of factors and their relative scarcities. The three phases are referred to as (1) hydrologic-hydraulic, (2) agricultural-based, and (3) farmer-oriented.

In the hydrologic-hydraulic phase, there is an emphasis on capture, conveyance, and distribution of the water and the structures and rules for accomplishing these tasks. Allocation rules tend to be simple, e.g., a fixed water duty throughout the system. Water is not managed as the scarcest resource. Management capability, including knowledge about irrigated agriculture, may be the scarcest production factor.

In the second phase, experience with irrigated agriculture and the operation of irrigation systems is gained and the relative value of agricultural production increases (often as a result of population increases), resulting in a greater concern for the use of water. Allocation rules may be changed to incorporate the agricultural characteristics of the system. Information about local soils, crop-water relationships, and other agronomic factors are incorporated into the design and operation of systems. The scarcest production factor is now the land that has been developed for agriculture, and the objective is to maximize the productivity of the land.

In the third phase, after more land has been brought into cultivation, water becomes the scarcest resource. Increased management and control of water are required to use the water more efficiently. This often involves increased farmer participation in the management of the system, and, hence, Levine refers to this as the farmer-oriented phase. "Equity considerations tend to be more complex, and the combination of efficiency, production, and equity concerns are reflected in relatively complex operating rules" (Levine, 1981:6).

From this discussion, it can be concluded that if the demand for the agricultural output from irrigation systems is the same across systems, more intensive management would be expected in systems where water is relatively scarce than in systems in which the water supply is relatively abundant. In the region of the mid-hills of Nepal where the research was conducted, there is a high demand for food. Differences in the intensity of management of irrigation cannot be attributed to variations in the demand for agricultural products and, therefore, in the derived demand for irrigation water.

4.2 Evidence from the Systems Studied

To study the determinants of management intensity and organizational structure, it was necessary to have a sample which included systems exhibiting different levels of management. The hypothesis that guided the selection of irrigation systems for study was that the degree of management intensity would be inversely correlated with the relative water supply. Levine's analysis has shown that the achievement of high water-use efficiencies requires more investment in physical structures (concrete-lined channels, control gates, measuring devices) and/or management activities (distribution by rotation or demand, 24-hour operation). By selecting research sites representing a range of water supply conditions relative to the potentially irrigable area, the aim was to study the affect of water supply on the technologies used and, particularly, on the management practices and organizational structure of the irrigation organizations.

The primary purpose of most water management activities is to reduce the chance that there will be yield reductions due to an inadequate water supply. There are exceptions in some places where the danger of yield reductions may be from water logging due to an excess supply of water, in which case the management activities would focus on reducing the supply and improving drainage.[4] However, more often the concern is to prevent the crop from suffering yield-reducing moisture stress as a result of an insufficient supply of water to the root zone relative to the rate of evapotranspiration.

---

[4]Under the conditions of the well-drained soils of the river terraces in the hill region of Nepal, water-logging and drainage are not a problem.

Water management activities in this type of situation are intended to increase the actual relative water supply. Since "relative water supply" (RWS) is defined as the water supply (rainfall plus irrigation) divided by the demand (evapotranspiration plus seepage and percolation), this increase in RWS can be accomplished by increasing the effective supply, reducing the demand, or a combination of the two. Water management activities can, thus, be separated into the categories of supply-enhancing and demand-diminishing. Some of the activities, particularly those for enhancing the supply, must be undertaken collectively by the irrigation organization, while others can be done individually by farmers on their fields.

4.2.1 Supply-enhancing Activities

Supply-enhancing activities as considered here do not include efforts that might be made to increase the supply in the river, stream, or spring that is the source for the irrigation system. An example of such an activity would be the reforestation of the hillsides so that more of the rainfall is retained longer in the watershed, yielding higher supplies in the dry season. The supply in the source is considered as given, and supply-enhancing activities are those which increase the amount of water that is extracted from the source and effectively reaches the root zones of the crops in the farmers' fields.

Organization Activities. The main supply-enhancing activities observed in the irrigation systems studied are maintenance of the intake and main canal. These activities increase the proportion of the available supply that is diverted and reduce the amount that is lost before it reaches the command area. As was described in Chapter 3, major routine maintenance of the systems is carried out by the organizations in June and early July just prior to the transplanting of the monsoon rice crop. Throughout the monsoon rice season, when a reliable supply is critical, there is intensive monitoring and maintenance of the systems. The main canal and intake are patrolled daily for early detection of leaks. Repairs are done either by the patrollers or by additional members of the organization who are mobilized to do the emergency maintenance. These monitoring and maintenance activities can require a considerable amount of labor, as much as 20 to 30 man-days per member household annually, i.e., more than 50 man-days per hectare in many systems.

The amount of labor required is a function of the type of source, topography of the intake location, type of intake structure, length of the main canal and type of terrain through which it passes, technology of the canal (e.g., lined or unlined, tunnels, stream-crossing structures, desilting devices), rainfall pattern and amount, run-off characteristics of the watershed, and silt load of the source. A source that is a spring will have lower maintenance requirements than a monsoon stream subject to great changes in level of discharge including violent flooding. Stone and brush diversion structures, which wash out when there is a heavy rain, need repair more often than permanent, concrete diversions. Long canals which traverse steep, unstable hillsides are subject to damage by landslides during the monsoon, requiring many man-days of emergency maintenance to restore the flow in the system. The monsoon rainfall pattern, with heavy rains concentrated in a short period of time, results in the need for more maintenance than if the rainfall were more evenly distributed throughout the year. The monsoon rains cause flooding and the destruction of diversion structures, and the heavy run-off carries a large amount of silt which must periodically be cleaned from the main canal.

Storage is another supply-enhancing activity. Excess supply during the wettest periods can, under certain conditions, be captured and stored for use at a later time instead of being allowed to flow past the intake or drain off the fields. Large-scale storage allowing for inter-seasonal reallocation of water is not practiced in the hills of Nepal. The structures required for significant storage of water on the monsoon streams are prohibitively expensive relative to the potential benefits from their construction.[5] Another type of supply-enhancing storage is practiced, however, in some of the farmer-managed systems. Small tanks are used to aggregate a small trickle for a fixed period of time, such as overnight. The water stored in the tank is then released in a short time period, with the much larger flow resulting in less water seeping into the canal bed and walls and more reaching the fields.

The high density of field channels is supply enhancing. Each separate field of every individual farmer is entitled to a field channel, i.e., field-to-field irrigation is not necessary in most of the systems observed. Under rotational distribution, water can be quickly channeled with a great deal of flexibility to any particular field without the losses incurred in traveling over other fields. A cost of this high field-channel density is that the land occupied by field channels is not available for production.[6]

---

[5]For a storage dam to survive the monsoon floods when the stream discharge may be 5,000 times what it is in the dry season would require massive structures, whereas the hydraulic command area of the dam would, in most cases, be quite small.

[6]Measurements were taken to estimate the amount of productive land occupied by bunds and field channels. The total was estimated to be approximately 10 percent; of this, less than a quarter would be taken up by the field channels.

Individual Farmer Activities. There are some activities that the individual farmer does that can be classified as supply-enhancing, although only in terms of his own supply and not the overall system's. These include checking to see that no one has closed the intakes to his fields, staying in the field during his turn (if distribution is by rotation) to make sure that he receives water for the full length of his turn, and plugging leaks that might develop in his fields' bunds. These activities require additional household labor input.

Stealing water is another supply-enhancing activity. This can be done by tampering with a proportioning weir (tilting it or partially blocking the other openings) so that more water passes through one's notch, taking water when it is not one's turn, and cutting unauthorized openings in the canal bund to allow more water to enter one's fields. Stealing can also be a collective activity of an organization if it steals from a system whose intake is a short distance upstream with a canal parallel but higher on the hillside. These activities require additional labor, but getting information on actual inputs to water-stealing activities is difficult and no attempt will be made to model them.

4.2.2 Demand-Diminishing Irrigation Management Activities

Organization Activities. Demand-diminishing water management activities are undertaken to reduce evapotranspiration (ET) and seepage and percolation (S&P). More of these activities affect seepage and percolation rates than than they do evapotranspiration. One common means of reducing the demand for water, which affects both S&P and ET and which is practiced to some extent by many irrigation organizations, is a restriction of the area that is irrigated. As was described in Chapter 3, in the hill irrigation systems of Nepal the area that is entitled to water is precisely defined. The allocation may change from season to season with the result that the area irrigated by a given system varies among seasons. The Raj Kulo organization in Argali represents a striking example of this. During the monsoon season, the area irrigated is strictly limited. However, the irrigated area is nearly doubled in the following season when wheat is grown. At this time, water is relatively less scarce (relative to the lower demand of the less water-intensive wheat crop), although in absolute terms the supply is much less than during the monsoon.

Another means of reducing demand is by restricting the crops that may be grown. The pre-monsoon season (mid-April to mid-July) is suitable for cultivating rice, and in irrigation systems such as the Damgha Kulo in Majuwa where the supply is plentiful, it is the main crop grown in this season. But in Chherlung, where the supply is considerably scarcer, the Thulo Kulo organization has a rule restricting members from growing rice during the pre-monsoon season. Everyone grows maize, a much less water-demanding crop.

Limiting the area with access to water and restricting the choice of crops are responses of an irrigation organization to long-term experience. As the system is improved over time, restriction of the area irrigated may not be so much a function of the water supply as it is a result of the accepted convention concerning property rights in water.

The method of water distribution also affects the demand for water, and this is a practice than can be adapted between and within seasons in response to changes in the supply. The description in Chapter 3 noted marked differences in the water distribution method for monsoon rice among systems with different water supplies and within systems as the supply varied over the season.

In systems where the supply is extremely abundant, there is little concern and attempt to precisely measure and deliver to each field its exact allocation. The Damgha Kulo system in Majuwa uses several _saacho_s to distribute a measured allotment of water from the main canal into secondaries. From the secondary level on, continuous-flow distribution without measuring devices is practiced. Water is roughly proportioned and diverted into tertiary canals and field turnouts using stones and mud. Because of the abundance of supply, no one is concerned about the accuracy of the proportioning.

In situations where the supply is somewhat less abundant, distributing the water in this way leads to conflict as individual farmers attempt to increase their supply by altering the temporary structures for approximate proportioning. To reduce conflict it becomes necessary to regulate distribution to a lower level of the system by using measuring devices. This may be accomplished by installing _saacho_s to accurately proportion water from secondaries to tertiaries and into field turnouts in a fixed ratio. In Argali, when a group of farmers being served by a tertiary could not agree to the approximate proportioning of water without measurement, _saacho_s were installed. While this does not diminish the actual physical demand for water, which is a function of the seepage and percolation and evapotranspiration rates, it does reduce the "psychological demand" for water. Farmers who have agreed upon the construction and installation of a _saacho_ are assured that they are getting their share of the water. With the approximate, unmeasured proportioning with stones and mud, farmers are suspicious that other members are tampering with these structures and stealing water, and each is tempted to try to do so himself to increase his supply.

Systems which have a scarce supply cannot distribute water continuously to the entire irrigated area. When the supply is low, the discharge apportioned to each field is not sufficient to reach the far end of the fields before it seeps into the soil near the turnout where it enters the field. The crops at the far end of fields may thus wither and die. Under the rotational distribution observed, a larger volume of water--usually all the flow in the secondary--is directed into one field for a specified length of time and then moved on to the next field. With this greater discharge, it is possible to cover the entire field.

Under continuous-flow distribution with standing water in the fields, water is constantly leaving the plants' root zone by deep percolation and seepage. In the systems studied, this element in the demand for water is extremely high, ranging from 20 ha-mm/ha/day early in the season to over 70 ha-mm/ha/day late in the season.[7] Thus, with distribution by continuous flow, there is a constant seepage and percolation demand of considerable magnitude. However, with rotational distribution, much of the time there is no seepage and percolation because there is no standing water in the fields. Since the volume of supply in the system is the same under either continuous-flow or rotational distribution, the reduction in demand which accompanies a

[7]One ha-mm refers to the volume of water represented by an area of one hectare with a layer of water one millimeter deep over it, i.e., 100 meters by 100 meters by 1 mm. It is a metric equivalent of the English term "acre-feet." A 20 ha-mm/ha/day supply of water would provide each hectare of area a volume of water equal to 20 ha-mm in a 24-hour period.

change from continuous-flow to rotational distribution results in an increase in the actual relative water supply.[8]

Farmers definitely prefer to practice continuous-flow distribution for rice. It was observed that this was always the method of distribution where the water supply was sufficient. Farmers said that they only used rotational distribution when the supply was scarce. There is some uncertainty as to whether rotational distribution requires more labor than distribution by continuous flow. Farmers of the Gal Oya Project in Sri Lanka reported that distribution by rotation saved them labor (Uphoff, 1985). Kathpalia (1984) reports the same information from farmers in Thailand. Ordinarily in the systems studied, continuous-flow distribution requires somewhat less labor, at least for actual distribution.[9] Farmers distributing water by continuous flow usually check their fields once a day, but this does not take them long. Those who were rotating, however, reported that they had to remain in their fields for the full length of their turn which might involve up to ten hours every second day.[10]

The Tallo Kulo organization in Thambesi, with the scarcest supply of all the systems studied, practices rotational distribution throughout nearly the entire monsoon rice season. In the Chherlung Thulo Kulo system, while

---

[8]Yoder (1986) presents a detailed analysis of the relative water supply in several of the systems studied which shows how, with a change to rotational distribution, the relative water supply rises above what it would be if distribution by continuous flow were retained. The analysis of Argali's Kanchi Kulo system in his Chapter 6 is a good demonstration of this.

[9]There is some evidence that farmers who know they will have to rotate do less intensive land preparation than those who are able to practice continuous-flow distribution throughout the season. This will be discussed later.

[10]It is possible that just prior to a switch from continuous flow to rotation, more labor is required than afterwards. Under continuous flow with a reduced supply of water, farmers may have to check their fields nearly continuously to make sure no one is stealing their water. After rotation is introduced, they only need to be there during their turn to receive water.

distribution from the main canal into secondaries is done continuously by means of saachos, below the saachos rotational distribution is often practiced. If during the season, in systems that normally practice continuous-flow distribution, the supply declines significantly with the result that all fields cannot be adequately irrigated in this way, the saachos are removed and a rotational system of distribution initiated. In 1982, this occurred in a part of Argali's Kanchi Kulo system. Beginning 52 days after transplanting, the farmers whose fields were served by one of the secondaries were not able to satisfactorily irrigate their fields by continuous flow.[11] A switch was made to rotational distribution which was practiced for the remainder of the season in this part of the system.[12]

This discussion of the technology and management practices used for distribution of the water has indicated how more intensive efforts are employed for the efficient distribution of water when the supply is relatively scarce than when it is abundant. Table 4.1 compares the relative water supply of the systems studied with the type of distribution that was observed in the monsoon rice season. The relative water supply used in this table is the net relative water supply (NRWS) which has been computed by taking the

---

[11]For reasons that will be discussed in Chapter 7, the fields served by this secondary received less water per unit area than did the rest of the area irrigated by the Kanchi Kulo.

[12]One other method of distribution was observed in one of the sites where a rapid appraisal was conducted. This method was a function of both the scarce water supply and the location of the farmers' homes relative to the fields. Distribution of the water was by contract; three members were paid by the organization to distribute the water as adequately as possible to all fields. The contractors rotated the water throughout the system as they determined would provide equitable irrigation to all fields. Most of the farmers in the organization lived a two- to three-hour walk from the command area, and to make the walk down to the fields and back each time it was one's turn to irrigate would have been a hardship. The three farmers who had the contract for water distribution lived in temporary shelters in the command area during the season. They were also responsible for such repairs as they could handle.

total irrigation supply for the season and dividing it by the total demand.[13] The table shows that the lower the NRWS (i.e., the scarcer the supply relative to demand), the more that methods of distribution are employed which provide more precise control and which require more investment of resources.

Table 4.1 Relative Water Supply and Method of Water Distribution

Organization	Water Supply/ Area Irrigated (NRWS)	Method of Distribution
Tallo Kulo, Thambesi	0.61	Rotation all season
Thulo Kulo, Chherlung	0.99	Saachos, rotation below secondaries
Tallo Kulo, Chherlung	0.90	Saachos, rotation below secondaries
Raj Kulo, Argali	1.34	Saachos down to field turn-outs
Kanchi Kulo, Argali	1.35	Saachos to tertiary level[a]
Saili Kulo, Argali	1.26	Saachos to tertiary level
Maili Kulo, Argali	1.18	Saachos to tertiary level
Damgha Kulo, Majuwa	1.75	Saachos, unmeasured below secondaries

[a]The farmers served by one of the secondaries used rotational distribution the second half of the season.

Individual Farmer Activities. Demand-diminishing activities are also undertaken by the individual farmer. The farmer's choice of crop, where he has a choice, has the largest impact on the demand for water. For instance, the decision to grow maize in the pre-monsoon season instead of rice results

[13]For this computation an average demand over the season of 4 liters/second/hectare has been utilized in calculating the total demand. While this may seem extremely high, it is what was consistently derived from the seepage and percolation measurements in the different sites. The soils are extremely well drained and the water table far below the surface, unlike the situation in the Philippines where much of the research on seepage and percolation in flooded rice has been conducted. Using this rate of demand and the area actually irrigated, the total demand has been calculated. The term "net relative water supply" has been used to distinguish it from "gross relative water supply" (GRWS), which will be defined later.

in a much lower demand for water. During the monsoon season, however, no one with access to irrigation chooses to grow a crop other than rice.

Land preparation for rice has a potentially significant impact on the seepage and percolation rate. Farmers reported that good land preparation can reduce the S&P rate by as much as 50 percent. This is done by executing more passes over the field when plowing and planking, making the plowed layer deeper, and digging by hand in the corners of the field and along the bunds where the bullock-drawn plow cannot reach. Obviously, more human and bullock labor is required to do this.

In these extremely well-drained soils where the water table is far below the surface, the depth of standing water in the field affects the rate of percolation, i.e., the deeper the water, the higher the rate of percolation.[14] Demand can, thus, be reduced by maintaining less standing water in the fields.

The individual farmer can also diminish demand by reducing the area cropped. If the supply becomes scarce to the point that his crop may fail or suffer significant yield reduction due to moisture stress, he may decide not to irrigate one or more terraces, thereby reducing his fields' demand and insuring that the remainder of his crop receives an adequate supply of water.

4.3 Analytical Model

The above section has described water management activities--both those of irrigation organizations and those of individual farmers--observed in the irrigation systems that were studied. The activities are conducted to raise the relative water supply above what it would be were they not employed. Observations showed that the scarcer the water supply relative to

[14]See Yoder (1986), Chapter 5, for a detailed discussion and analysis of this phenomenon.

the demand for irrigation, the more intensive was the management of its distribution. An attempt will now be made to model an irrigation system for the purpose of analyzing the utilization and impact of some of these activities. In the context of a linear programming model, the effects of water management activities are as follows:

1. Supply-enhancing activities relax the water supply constraint.

2. Demand-diminishing activities reduce the input coefficient of water in production of a crop.

In general the way in which supply-enhancing activities are built into the model is such that an expenditure of labor is required for each additional unit of water supplied, and the added water is supplied through a water balance equation. The water balance equation includes the water supplied, water used in crop production, and excess supply that leaves the system as drainage. The potential irrigation supply is constrained to be no more than the amount of water available in the source.

Demand-diminishing activities allow the same level of yield to be achieved with a lower input of water per hectare. If the demand-diminishing activity is not included in the solution, the production of a given yield per hectare will require a higher input of water; for purposes here, the technical coefficient for water to produce that yield will be A_1. If the demand-diminishing activity is included, then the same yield can be attained with a lower input of water; here the technical coefficient for water will be A_2 where A_2 is less than A_1. Note that the crop production activity with the technical coefficient for water of A_2 can only enter the solution if there is a demand-diminishing activity, which requires the expenditure of labor, also included in the solution. For instance, if rotational distribution is done, then a specific yield level could be attained with less water than if distribution were by continuous flow.

4.4 The Linear Programming Model

A linear programming model to analyze the relationship between water supply and management activities was built using field data, primarily data from the Kanchi Kulo of Argali. The model represents the Kanchi Kulo irrigation system and analyzes the operation of the system in the monsoon rice season. This is the only season in which intensive irrigation management is practiced, and monsoon rice is the primary crop for which the system and organization are designed. The focus of the analysis is on the utilization of water, the activities for managing the water more or less efficiently, and the impact of the management practices on the output of the system. The outline of the model showing the activities and constraints is presented in Table 4.2.

4.4.1 Objective Function

The objective function of the model is the maximization of the net cash value of production in the irrigation system, i.e, the total production multiplied by the farmgate price less cash expenses for production inputs such as labor, bullocks, and fertilizer. This is different from maximizing net income for which only income from actual sales would contribute to the objective function. Most of the rice is produced for home consumption, and few of the sample farmers sold any.

4.4.2 Crop Production

In the model, rice can be produced under two different levels of adequacy of water supply, one which results in no reduction of yield due to water stress and the other in which the moisture stress significantly reduces

Table 4.2 Outline of the Model

ACTIVITIES / RESOURCES		Crop Production HY (3)	LY (3)	Water Management SE (3)	DD (3)	Buy Inputs C (6)	Raise Bullocks (1)	Drainage (3)	Cropped Area (1)	Costs (1)	Constraint	
Unit		ha	ha	man-day	ha	qty	bullocks	ha-mm	ha	Rs.		
Income/cost		A1	A2	0	0	0	0	0	0	A3		
Cropland Inventory	(1)	1	1	0	0	0	0	0	−1	0	<=	0
Available Cropland	(1)	0	0	0	0	0	0	0	1	0	<=	Cropland
Owned Bullocks	(1)	0	0	0	0	0	1	0	$-a_{ij}$	0	<=	0
Bullock Inventory	(1)	a_{ij}	a_{ij}	0	0	−1	$-a_{ij}$	0	0	0	=	0
Supply Enhancement	(3)	0	0	1	0	0	0	0	0	0	<=	Limit
Water Inventory	(3)	a_{ij}	a_{ij}	$-a_{ij}$	0	0	0	1	0	0	<=	Supply
Labor Inventory	(3)	a_{ij}	a_{ij}	a_{ij}	a_{ij}	−1	a_{ij}	0	0	0	=	0
Plowman Inventory	(1)	a_{ij}	a_{ij}	0	a_{ij}	−1	0	0	0	0	=	0
Rotation Inventory	(2)	1	1	0	−1	0	0	0	0	0	=	0
Extra Land Prep. Inventory	(1)	1	1	0	−1	0	0	0	0	0	=	0
Fertilizer Inventory	(1)	a_{ij}	0	0	0	−1	0	0	0	0	<=	0
Cost Inventory	(1)	0	0	0	0	1	0	0	0	−1	=	0

HY: Unstressed crop. 3 different water management regimes.
LY: Stressed crop. 3 different water management regimes.
SE: Supply-enhancing maintenance (3 periods)
DD: Demand-diminishing: extra land preparation.
rotational distribution (period 3 only and periods 2 and 3).

C (inputs): Labor (3 periods)
Plowman
Bullocks
Fertilizer

yields. In Argali and Chherlung (examples of the first level of water adequacy) analysis of the crop cut data revealed no significant correlation between yield and stress days. This is because the sample plots all received enough water that yields were not reduced because of moisture stress. However, the tail section of the Tallo Kulo system in Thambesi (an example of the second level of water adequacy) suffered high stress, and when these plots are included in the analysis, there is a significant inverse correlation between yield and stress. In the model, the yield level for rice grown under stressed conditions was estimated to be the average of the yield of the plots in Thambesi which suffered from high stress, i.e., 1.6 tons per hectare. The unstressed yields were estimated by averaging the yields of the crop cuts in Argali, Chherlung, and Majuwa. This came out to be approximately 3.5 tons per hectare.

Production function analysis of the crop cut data revealed no significant response to the application of fertilizer. On the average, farmers in Argali applied 45 kg/ha of complex (NPK: 20-20-0) and 72 kg/ha of urea, i.e., approximately 40 kg/ha of nitrogen and 9 kg/ha of phosphorus. For the model it is assumed that the rice grown without stress is fertilized at this rate, and that which is stressed has no fertilizer applied, as was the case in Thambesi where the stress was observed.

4.4.3 Water Management

The primary decisions in the model are whether or not to carry out supply-enhancing and/or demand-diminishing management activities. Modeling of all of the management activities described above was not attempted--only those considered the most significant and for which data are available or could be estimated. The supply-enhancing activity in the model is the daily patrolling and maintenance of the intake and main canal throughout the season. Demand-diminishing activities included in the model are extra land preparation to reduce seepage and percolation and rotational distribution instead of continuous flow. Each of these activities requires some additional labor inputs. Thus there is a trade-off between water and labor (management) in production within the system.

4.4.4 Water Supply

For the model, the growing season has been divided into three one-month periods covering the period from just after transplanting until late in the season when farmers stop applying water to the fields to allow them to dry for the harvest. It is assumed that in each period there is a base flow available each day without doing any maintenance to the system.[15] This amount was calculated by taking the average of the daily discharges for the month and subtracting one standard deviation from it. By doing the supply-enhancing daily patrolling and maintenance, it was assumed that the supply could be enhanced by up to but no more than this amount of one standard deviation. The rationale for making it a standard deviation is the way in which the supply was observed to vary. During the season, the supply would gradually decline for several days as the intake and canal developed leaks. After several days of decline, the organization would make the needed repairs to increase the supply arriving at the command area. Table 4.3 displays the water supply information for the model.

---

[15] This is not exactly realistic as sometimes landslides completely interrupt the flow and make it impossible to irrigate again without doing maintenance work.

Table 4.3 Water Supply for Model

Month	Base Flow	Potential Enhancement
One	472 ha-mm/day	122 ha-mm/day
Two	208	188
Three	440	144

For the model, the labor required for maintaining the canal during the season was calculated from the six years of labor attendance records that were available from the Kanchi Kulo organization. These data are presented in Table 4.4. Thirty man-days per month, representing one person patrolling the canal each day, are added to these figures to estimate the total monthly supply-enhancing labor.

Table 4.4 Emergency Labor[a] - Kanchi Kulo, Argali

Year	Month 1	Month 2	Month 3
1978	49	23	0
1979	43	17	21
1980	15	117	0
1981	96	17	0
1982	106	13	95
1983	66	40	24
Average	63	38	23
+ Daily Patrol	30	30	30
Total Supply-Enhancing Labor	93	68	53

[a]man-days/month

4.4.5 Water Demand

The additional labor requirement for the demand-diminishing activities is less well documented. As previously noted, farmers reported that the rate at which the water infiltrates in khet fields can be reduced by as much as 50 percent by more intensive land preparation. The irrigated area of the Kanchi Kulo can be divided into two sections, one which has a high water allocation and one, a low allocation. The high-allocation area is entitled to and receives 2.7 times as much water per hectare as the low allocation section (Yoder, 1986). One would expect that farmers in the low-allocation area would invest more effort in land preparation to reduce the rate of seepage and percolation than farmers in the high-allocation area. However, this was not the case in our sample. Thee farmers with fields in the high-allocation section reported an average of about 33 plowman- and bullock-team-days per hectare for land preparation and 38 man-days of labor per hectare for repairing the bunds. For farmers in the low-allocation area, the figures were only 20 and 27 respectively. One possible explanation could be that the soils were different with the soil in the low-allocation area having a significantly lower infiltration rate. However, analysis of the soils and the seepage and percolation rates did not support this explanation (Yoder, 1986, Chapter 6).

Another explanation could be that farmers in the low-allocation section knew that they did not have a sufficient supply to distribute water continuously for the entire season but would have to switch to rotational distribution. In such a case, reducing the seepage and percolation rate through more intensive land preparation would not be as important as in the case where continuous flow was practiced for the entire season (as in the high-allocation section). For farmers practicing continuous-flow distribution, the water-holding capacity of the fields would be very important. They would not want the fields ever to dry to the extent of cracking. As they know from experience and as was confirmed by the data on infiltration rates, this would render continuous-flow distribution impossible because of the amount of water that would be needed to maintain standing water in the fields. The seepage and percolation rates recorded in the several fields which did crack increased dramatically (Yoder, 1986, Chapter 5).

Initially for the model it is assumed that this is the case. The farmers with the higher water allocation do more intensive land preparation to try to reduce the seepage and percolation so that they can distribute the water by continuous flow throughout the entire season. The amount of land preparation required to produce a crop with continuous-flow distribution is set at the amount observed in the section of the system which used continuous flow the whole season--33 plowman- and bullock-team-days for plowing and 38 man-days for repairing bunds and digging in the corners where the plow could not reach. If rotational distribution is done, then the amount of land preparation is set at 20 plowman- and bullock-team-days and 27 man-days, as was observed.

As mentioned earlier, another way to diminish the demand is to shift to a rotational distribution. Since the fields are not flooded at all times under rotation, the seepage and percolation term in the water demand is zero when there is no standing water in the field, leaving evapotranspiration as the only element in the demand expression. The labor required per hectare per month for rotational distribution was estimated to be 19 man-days. This was based on the low-allocation area of Kanchi Kulo where rotational distribution was practiced for part of the season on 3.7 hectares, the area served by one of the secondaries. When distribution is by rotation, the person whose field is being irrigated must be in the field at all times--day or night--meaning there is always one man engaged in water distribution. Therefore, a total of 720 man-hours are required per month for this rotation irrigation. If a man-day is considered to be 10 hours, then in a month, a total of 72 man-days are required for this 3.7 hectares, or approximately 19 man-days per hectare.

For continuous-flow distribution, an estimated 3 man-days per hectare per month are required. This is based on a farmer spending one hour per day checking his fields. The amount of time it takes him to walk from his house to check his fields and the time he is in the fields probably does not vary much with the amount of land he is irrigating, whether it be a quarter hectare or a hectare. The additional labor needed for distribution by rotation over and above that required for continuous-flow distribution is thus approximately 16 man-days per hectare per month.

For the model, the average demand for each month in ha-mm/ha/day for each type of management practice was estimated based on the analysis of demand in Yoder (1986). The average demand per 24-hour period for each of the three monthly periods and the method of distribution is shown in Table 4.5.

Table 4.5 Average Monthly Irrigation Demand (ha-mm/ha/day)

	High Allocation Area		Low Allocation Area	
Month	Demand	Distribution	Demand	Distribution
1	30.5	Cont. Flow	30.5	Cont. Flow
2	28.0	Cont. Flow	13.5	CF/Rot.[a]
3	69.0	Cont. Flow	27.5	Rotation

[a]Changed from continuous-flow to rotational distribution early in the month.

For this table, demand for irrigation water was estimated from the measurements of evapotranspiration and seepage and percolation, taking into consideration the depth of standing water and the fact that the rate of measured infiltration increased over the season. Under rotational distribution, it was assumed that for the days in which the land did not receive irrigation, there was no seepage and percolation demand. For more detail of the calculations of demand, see Yoder (1986), Chapter 6.

To grow an unstressed crop under continuous-flow distribution throughout the season, the actual irrigation demand (actual demand less rainfall) measured for the high-allocation area is used as the demand in the model. For distribution by rotation in the model, the demand is assumed to be equal to the demand calculated in the low-allocation area after the implementation of rotational distribution. For each situation, it is assumed that the water demand of a crop suffering yield-reducing stress would be half that of the unstressed crop. In other words, with half the supply required in the model to grow an unstressed crop under the different management regimes, it would be possible to grow a crop which would yield less because of suffering from moisture stress. Table 4.6 presents the water demand in each month for the different water management regimes.

Table 4.6 Irrigation Demand (ha-mm/ha/day)

	Unstressed Crop (Yield = 3.5 tons/ha)			Stressed Crop (Yield = 1.6 tons/ha)		
Crop Code	HY1	HY2	HY3	LY1	LY2	LY3
Distribution	CF[a]	Rotate Month 3	Rotate Months 2 & 3	CF[a]	Rotate Month 3	Rotate Months 2 & 3
Month						
1	30.5	30.5	30.5	15.3	15.3	15.3
2	28.0	28.0	13.5	14.0	14.0	6.8
3	69.0	27.5	25.0	34.5	13.8	12.5

[a]Continuous flow the whole season.

In Table 4.6, crop code HY1 refers to a rice grown under continuous-flow throughout the season, HY2 has continuous-flow in the first two months and rotation in the third, and HY3 has continuous-flow in the first and rotation in the second and third. The stressed crop, codes LY1, LY2, and LY3, have the corresponding management regimes but only half the amount of water is needed to produce these lower yields. These codes will be used in reporting the results of the linear programming model. The number of hectares of rice grown under each management regime will be reported.

4.4.6 Labor

The labor requirements per hectare in each month were calculated from the interviews of sample farmers which included their recall of how many laborers they used for different operations.[16] Work activities in the first month include land preparation (plowing and repairing of bunds), transplanting, and on-farm water management. An estimated 91 person-days of labor per hectare are required for these activities. This amount does not include the extra labor for more intensive land preparation to reduce seepage and percolation. In month two, the activities are weeding and on-farm water management, adding up to a total of 52 person-days per hectare. The labor for on-farm water management does not include the additional required for rotational distribution. In the third month, the only activity is on-farm water management for a total of seven person-days per hectare.

[16]A questionnaire was administered two times for each cropping season. The first time was after planting and weeding were completed and the second after harvest. The recall data concerning labor use in rice production seemed of a higher quality than that for the other crops. For rice, each activity was accomplished in a short time, almost always with the use of some hired and/or exchange labor in addition to household members. These two factors, that each activity was completed in just a few days and that outside labor was involved, aided the farmers' recall.

Labor for harvesting and threshing, which is a significant percentage of the total labor expended in rice production, is not needed until after irrigation of the crop has been terminated and is, therefore, not relevant to decisions concerning resources allocated to irrigation management. While the amount of labor required for the harvest and post-harvest tasks is a function of the yield level, it is very unlikely that the decisions concerning the employment of water management activities to achieve higher yield levels are affected by the possibility of a labor constraint when harvesting and threshing are done. In the research sites, no evidence of such a practice was found.

For the model, the supply of household labor per hectare was calculated on the basis of information given by the sample farmers as to the number of persons in the household who participated in the farming operations.[17] An average of 13 household members per hectare engaged in the farm work. However, these persons are also occupied with other activities including water carrying, gathering fodder, and herding. The amount of time engaged in these tasks was subtracted from the amount of household labor available, resulting in 10 persons per hectare per day.

Land preparation and transplanting in Argali was accomplished in a very short time. In 1982, the standard deviation of the date of transplanting was only five days. For the model it is assumed that these activites are accomplished over the entire system in a 10-day period. Thus, the total household labor available per hectare is estimated at 100 person-days in the first month and 300 in the following two. Wage rates for hired labor are different for different tasks. Laborers for plowing and repairing bunds are paid more than those who transplant and weed the rice crop. Accordingly,

---

[17]A detailed questionnaire concerning general socioeconomic characteristics of the household, including labor participation in various activities, was conducted in two sittings with the sample households.

the wage rate in the first month is set at Rs. 10 per day and in months two and three, at Rs. 7 per day.

Based on the interviews of the sample farmers, the number of pairs of bullocks owned per hectare by the households in the system was computed to be 1.67. Thus, for each hectare cropped, the model assumes there to be 1.67 pairs of bullocks available for plowing. It was also estimated that 0.3 persons per day were required to cut fodder and graze one pair of bullocks. The rental rate for bullocks was Rs. 10 per day for a pair. Nearly all farmers hired one or more plowmen even if they raised their own bullocks. Brahmins are forbidden by Hindu religious tradition from plowing, and all but three of the sample farmers in Argali were Brahmins. The plowman's wage rate was Rs. 10 plus two full meals, tea and snacks twice a day, cigarettes and whiskey. In the model, the daily wage rate for hired plowmen is set at Rs. 15. The production is valued in the model at Rs. 2.85 per kg, the farmgate price reported by the few farmers in Argali who sold rice.

4.4.7 Results

The model was first run with the coefficients derived from the field data as described above, and the results are presented in column one of Table 4.7. (The symbols used in Table 4.7 are defined in Table 4.8 immediately preceding it.) An interesting result is that even though there is plenty of water, rotational distribution is practiced over the entire irrigated area of 10.7 hectares (i.e., the only crop production activity in the solution is HY2 which represents production with rotational distribution in month 3).[18] The extra labor required for land preparation for continuous-flow

[18] The total area irrigated by the Kanchi Kulo system was 11.3 hectares. However, 0.6 hectare was irrigated by a secondary which took off from the main canal above the flume which was installed to measure the system's supply.

distribution renders it a less than optimal activity according to the model. Observation of farmers' actual irrigation practices, however, revealed a strong preference for distribution by continuous flow.

There may be several reasons for this discrepancy. First, farmers may attribute a higher cost to the labor involved in rotational distribution, particularly needing to go out at night to irrigate, than the model does. This might be termed the "dukha-factor." "Dukha" is a Nepali word meaning pain, aggravation, bother, etc. While the actual time in number of man-days required for rotational distribution might be less than the number required for extra land preparation to maintain continuous-flow distribution, the farmers may consider those days and nights doing rotational distribution as much more of a hardship or dukha. They have to stay alone in the field for the duration of their time to get water, and half the time this is at night.[19] Sensitivity analysis was done on the model to see what the dukha-factor would have to be to reproduce the observed situation of 7 hectares irrigated by continuous flow and 3.7 by rotation in the second half of the season. It turned out that a dukha-factor of approximately 6 resulted in the output in column two of Table 4.7, showing the same water management activity as was observed in the field.

Another more likely reason for the preference for continuous-flow distribution relates to the security of yields. With continuous-flow resulting in water standing in the fields at all times, farmers can be sure of the water status of their fields. When the fields are periodically dry under rotational

[19]Farmers from the Raj Kulo system in Argali reported that they often slept in their fields before improvements were made in the canal which increased the system's flow sufficiently to enable continuous-flow distribution. A major expense of irrigation cited by farmers in systems where rotational distribution is practiced is the cost of batteries for flashlights, needed for nighttime irrigation.

distribution, there may be some undetected moisture stress. Also, there may be times during the season when the supply is interrupted for several days by a landslide. At such times, if there is standing water in the fields under continuous-flow distribution, the interruption is not as likely to threaten yields as if the fields have been dry already under rotational distribution when the disruption occurs. The implication of this would be that, if looked at over a number of years, the yields in the low-allocation area where rotation has to be practiced would average less than where distribution is by continuous flow. (The year that the system was studied may have just happened to be one when the area under rotation did not suffer any yield-reducing stress, while in other years it would have.)

To analyze how much this yield reduction would have to be, on the average, to make continuous-flow distribution preferable even though it requires more effort for land preparation, senstitivity analysis was done on the yield of the crop grown under rotation in the latter part of the season.[20] According to the model, if the average yield under rotational distribution drops from 3.5 to 3.3 tons per hectare, then distribution by continuous flow would be preferred. This does not represent much of a reduction on the average, but if there would be some years that the crop irrigated by rotational distribution would completely fail while fields irrigated by continuous-flow would produce a crop, this would contribute strongly to a preference for continuous-flow distribution. The results are presented in column three of Table 4.7.

---

[20]For this analysis, the labor utilized in rotation was not adjusted by the <u>dukha</u> factor.

Table 4.7 Model Results

	Base Case	Dukha Factor = 6	Rotation Yields = 3.3 tons
Crop Production (ha)			
HY1	0.0	7.0	7.0
LY1	0.0	0.0	0.0
HY2	10.7	3.7	3.7
LY2	0.0	0.0	0.0
HY3	0.0	0.0	0.0
LY3	0.0	0.0	0.0
Supply-Enhancing Activities			
SE1	0	0	0
SE2	1	1	1
SE3	0	1	1
Demand-Diminishing Activities			
ELP	0.0	7.0	7.0
ROT2	0.0	0.0	0.0
ROT3	10.7	3.7	3.7
Drainage (ha-mm)			
Period 1	146	146	146
Period 2	96	96	96
Period 3	146	0	0
Dual Price of Water (Rs./ha-mm)			
Period 1	0	0	0
Period 2	0	0	0
Period 3	0	2.6	5.4
Dual Price of Land	Rs. 7,687	7,164	6,967
Objective Function	Rs. 81,771	77,319	76,879
Rice Produced (tons)	37.45	37.45	36.7

Table 4.8 Symbols Used in Presenting Model Results

HY1: Unstressed rice crop (yield = 3.5 tons) grown under continuous-flow distribution all season.
HY2: Unstressed rice crop grown with continuous-flow distribution months 1 and 2 and rotational distribution month 3.
HY3: Unstressed rice crop grown with continuous-flow distribution month 1 and rotational distribution months 2 and 3.

LY1: Stressed rice crop (yield = 1.6 tons) grown with continuous-flow distribution all season.
LY2: Stressed rice crop grown with continuous-flow months 1 and 2 and rotational distribution month 3.
LY3: Stressed rice crop grown with continuous-flow month 1 and rotational distribution months 2 and 3.

SE1: Supply-enhancing maintenance, month 1. (1 = yes, 0 = no)
SE2: Supply-enhancing maintenance, month 2.
SE3: Supply-enhancing maintenance, month 3.

ELP: Number of hectares on which extra land preparation done.
ROT2: Number of hectares on which rotational distribution done month 2.
ROT3: Number of hectares on which rotational distribution done month 3.

The results in column one present the optimal solution derived by the model using the coefficients developed from data collected in the field. Columns two and three show the results from the two alternate ways of trying to explain why the observed water management practice was different from that given as the optimum by the model.

There is some uncertainty as to whether farmers actually perform less land preparation if they know they will have to change to rotational distribution. Farmers in Chherlung, where they rotated part of the season, and in Majuwa, where continuous-flow was practiced the whole season, both did about the same amount of land preparation as those in Argali who distributed water by continuous flow all season. Thambesi farmers, who rotated most of the season, reported considerably more labor for land preparation, but they did not face the same need for a quick turnaround since their fields were fallow prior to the monsoon rice crop.

A model with all farmers doing the same amount of land preparation was run to analyze the trade-off between water and management labor.[21] The solution for the observed water supply was the same as that in columns two and three of Table 4.8 in terms of area on which different water management activities were employed. Since there was no drainage in the third month, the sensitivity analysis was done on the supply in this period to see how the management labor would vary as the supply varied. An isoquant of constant production from the 10.7 hectares of 37.45 tons was derived and is presented in Figure 4.3. As the daily water supply in month three is varied from a high of 739 ha-mm/day to a low of 124 ha-mm/day, the shadow price of water increases from 0 to Rs. 282 per ha-mm. With a high water supply, the entire area is irrigated by continuous flow. When the supply drops below 739 ha-mm/day, supply-enhancing labor in month three enters the solution. As the supply drops below 595 ha-mm/day, irrigation by rotation in period three enters the solution. At a supply of only 150 ha-mm/day, irrigation by continuous flow drops out of the solution, leaving the entire area irrigated by rotational distribution. Production by rotation in both months 2 and 3 begins to be in the solution.[22] If the supply falls below 124 ha-mm/day, rotational distribution is practiced over the entire area in both months two and three, and supply-enhancing labor in month two drops

---

[21]For this part of the analysis, all labor including that of the household was valued at the local wage rate.

[22]In building the model, an assumption was made that the demand in month 3, if rotation were practiced in month 2, would be slightly lower than if rotation was first implemented in month 3. This might be the case because the procedures of rotation would have been well established if already implemented for a month. There might be some wastage of water at the beginning of initiation of rotation.

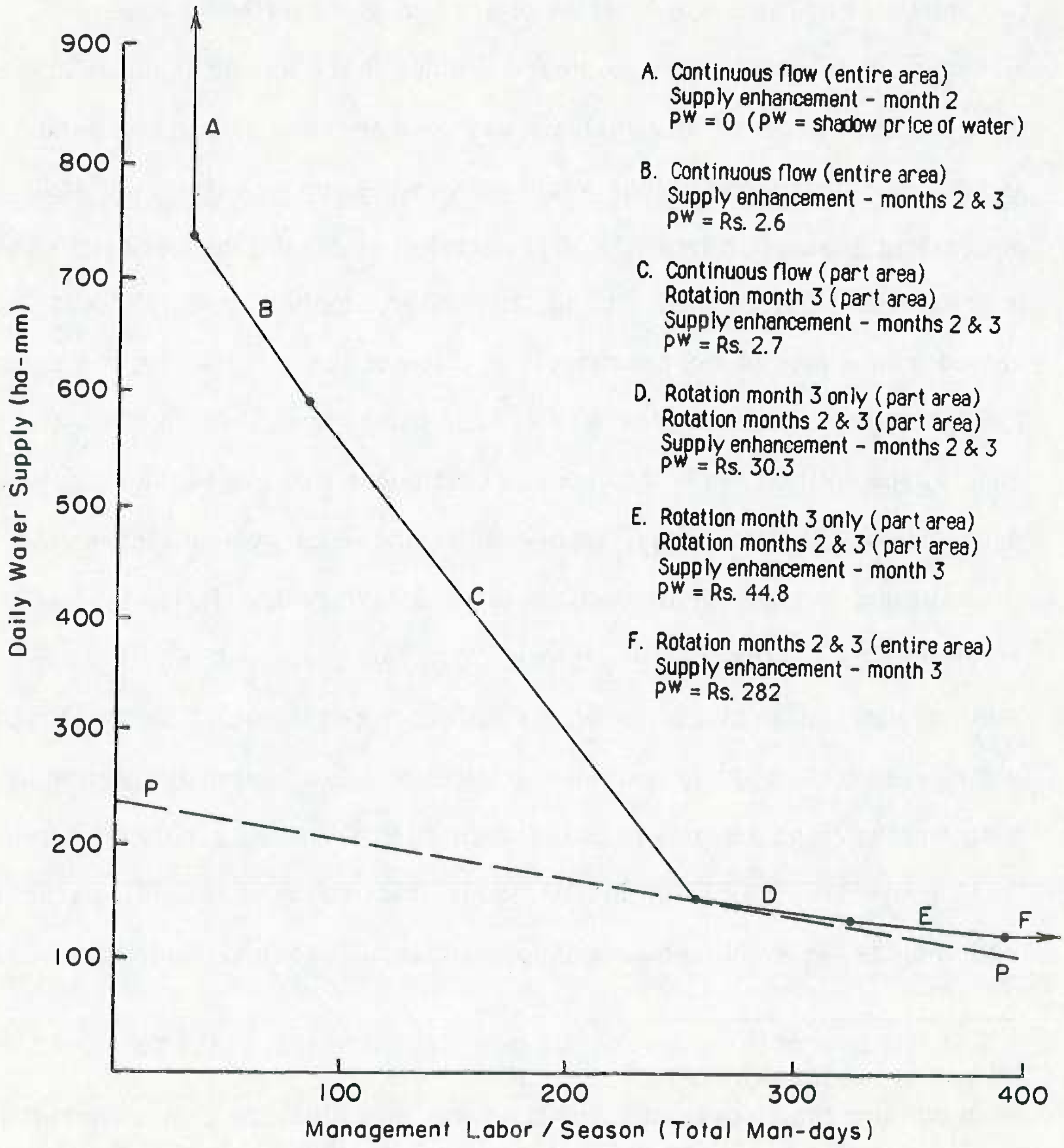

Figure 4.3 Isoquant

out.[23] At this point, also, land goes out of production and the results are no longer on the isoquant. At this level the water has its highest value, Rs. 282 per ha-mm.

The results of the linear programming model, confirming field observations, show that when the water supply is low, more effort is put into water management activities than when it is high. More management intensive methods of distribution were employed when the supply was relatively scarce than when it was abundant, as Table 4.1 demonstrated. In systems with a high net relative water supply, distribution was by continuous flow throughout the system--either unmeasured or proportioned by saachos depending on the NRWS--while those systems with a lower NRWS had to use a more labor-intensive rotational distribution.

A more interesting finding was that, using coefficients and prices observed in the field, the model found distribution by continuous flow to be suboptimal. Two possible explanations were given for why the farmers prefer to distribute water by continuous flow: the dukha-factor and the security of yields. While I think the dukha-factor enters in to some degree, the concern that yields might be reduced and a crop perhaps lost altogether is likely the more important element in the farmers' decisions about land preparation and water distribution.

The original hypothesis posited that systems with scarce water supplies would have more highly structured organizations to achieve more intensive management. In Chapter 5, the relationship between the water supply and the structure of the irrigation management organizations will be examined.

[23]Since distribution is by rotation in month two also, reducing demand considerably, supply-enhancing labor is not needed in that month.

CHAPTER 5: ORGANIZATIONAL STRUCTURE: FOR WATER DISTRIBUTION OR WATER ACQUISITION?

In this chapter the focus of the analysis is on the structure of the farmers' irrigation management organizations and the determinants of the level of organizational structure. It was expected that organizational structure would vary among systems, and an aim of the study was to understand, in broad terms, the factors causing the organizations to be structured differently. By understanding the structure of the management organization of systems in which the farmers are in complete control of all the irrigation activities, it was hoped that conclusions could be drawn about the appropriate type of farmer organization to develop in irrigation systems constructed by the government.

As has been explained before, the hypothesis that guided the development of the research and the selection of the research sites was that the level of structure of the farmer irrigation organizations would be inversely correlated with the water supply relative to the area that could be irrigated. There are also other factors that may contribute to the level of structure. It may be that the relationship of structure to water supply is not purely an inverse relationship but rather an inverted U-shaped one, i.e., little structure at the extremes of water supply and more in the middle of the spectrum. If a system is not irrigating the entire hydraulic command area, it may be that a more structured and stronger organization is needed to limit the access to the water and prevent those on the periphery from stealing water or pressing to somehow require the organization to allow them access to water. Certainly the need for organizational structure is likely related to the size of the organization, at least when it reaches a certain threshold. Some attention will be given to these factors. Finally, the need to mobilize resources every year for the ongoing maintenance of the system will be argued to be the most significant factor in determining the level of organizational structure observed in farmer-managed irrigation systems in the hills of Nepal.

Before analyzing the various possible determinants of organizational structure and several alternative hypotheses regarding the importance or dominance of certain ones, it is necessary to rate the level of organizational structure of the different irrigation management organizations which were studied. The rating of levels of organizational structure is not something than can be done according to a set of well-developed, objective criteria. There will, of necessity, be an element of subjectivity in the assigning of levels. This subjective part of the evaluation is based on more than one and a half years of intense involvement with the members and observation of the organizations. In this amount of time, one can get a good "feel" for the relative level of structure of an organization.

In Chapter 3, the structure of the organizations was described with reference to designated roles within the organization, its meetings, and the type of written records that it maintains. For rating the level of organizational structure, these are taken as indicators, and when they are aggregated, as in Table 5.1, the rating that results fits quite well with the subjective "feel" that was developed during the time spent in the different communities. In Table 5.1 one point has been given for the existence of each of the following: a management committee, a membership list, a record of members' water allocations, a written attendance record, written accounts, minutes of meetings, a written constitution, regular meetings, and

Table 5.1 Summary of Organizational Structure

System	Number Officers	Management Committee	Regular Meetings	List of Members	Work Attendence Record	Accounts	Minutes	Constitution	Fines	Total
Tallo, Thambesi	0	0	1	0	0	0	0	0	0	1
Thulo, Chherlung	11	1	1	1	1	1	1	0	1	19
Tallo, Chherlung	10	1	1	1	1	1	1	0	1	18
Raj, Argali	10	1	1	1	1	1	1	1	1	18
Kanchi, Argali	2	1	1	1	1	1	1	0	1	9
Saili, Argali	3	1	1	1	1	1	1	0	1	11
Maili, Argali	2	1	1	1	1	1	1	0	1	9
Damgha, Majuwa	1	1	1	1	0	1	0	0	0	5

established sanctions (fines). To this is added the number of designated functionaries or officers of the organization. There is some question as to whether this number should be added to the others, but the higher this number, the more role specialization there is which is an indicator of organizational structure. Table 5.1 shows three clusters of ratings, 18-19, 9-11, and 1-5. Combining with these numbers the subjective evaluation yields four levels of organizational structure among the systems studied: very high, medium, low, and very low. The ratings 5 and 1 for Majuwa and Thambesi are quite far apart, and the respective organizations are enough different that it justifies putting them at the two different levels of low and very low. Table 5.2 presents the levels of organizational structure observed. This rating will be used throughout the chapter whenever comparing the levels predicted by a hypothesis with the actual observed levels.

Table 5.2 Observed Levels of Organizational Structure

System	Indicator[a]	Rank Order	Rating
Thulo Kulo, Chherlung	19	1	Very High
Raj Kulo, Argali	18	2	Very High
Tallo Kulo, Chherlung	18	2	Very High
Saili Kulo, Argali	11	4	Medium
Maili Kulo, Argali	9	5	Medium
Kanchi Kulo, Argali	9	5	Medium
Damgha Kulo, Majuwa	5	7	Low
Tallo Kulo, Thambesi	1	8	Very Low

[a]Total from Table 5.1.

5.1 Organization as a Function of Relative Water Supply

To achieve a high degree of management intensity, it was expected that the management organization of systems with relatively scarce water supplies would be more structured and formal than that of systems in which the water supply was relatively abundant. A stronger organization with clearly defined rules and sanctions would be required to efficiently capture, convey, and equitably distribute a scarce supply of water among the member farmers' fields than would be needed if the supply were abundant. As was pointed out in Chapter 1, increased management intensity includes not only more control over water (physical control), but also increased control over human behaviour (social control), resulting in the need for a more formal or structured organization. An organization distributing water by rotation requires a specified distribution plan and the ability to discipline its members to follow the rotation. If water is scarce, there will be more likelihood of water stealing and conflict; hence a method of managing conflicts, including a process for adjudicating complaints and applying and enforcing sanctions against offenders, is needed. Downing (1974) refers to this as the "excess-scarcity hypothesis." The hypothesis is of the form "scarce water = more conflicts = more social control" (1974:119). He argues that it is not scarcity per se, but scarcity relative to the crop's demand for water, i.e., a low relative water supply, that leads to more conflict necessitating more social control. He hypothesizes that "water scarcity during the [crop's] moisture-sensitive period forces some kind of rigid social organization to allocate water" (1974:121).

The irrigation organizations which were studied intensively for one and a half years will now by analyzed in light of the hypothesis that the level of organizational structure is inversely correlated with the water supply. This comparison among systems analyzes the organizations for irrigation management during the monsoon rice season. The primary purpose of all the systems is irrigation of the monsoon rice crop, and it is for carrying out the activities necessary to successfully irrigate this crop that the organizations have been structured. Some intra-system comparison of management practices in non-monsoon seasons will also be included.

For this analysis two relative water supply terms need to be defined--"gross relative water supply" (GRWS) and "net relative water supply" (NRWS). The GRWS is defined as the ratio of the available water supply to the water needed (water demand) to grow a crop on the potentially irrigable land area, i.e., the hydraulic command area.[1] The NRWS is defined as the ratio of the water supplied by the system to the water needed to grow a crop on the actually irrigated land area. The crop assumed in the analysis is rice, and the demand is an average figure for the season assuming the soil is kept in a permanently saturated state without standing water on the surface.[2] For all the systems studied, the measured seepage and percolation and evapotranspiration rates were nearly the same. These river terraces are all well-drained, alluvial soils, and it is, thus, not surprising that seepage and percolation rates are approximately the same in all the sites. Calculation of this saturated conductivity[3] of the different plots in which seepage and percolation rates were measured yielded results ranging from 5 to 70 mm/day at the beginning of the rice season to 40 to 170 mm/day at the end of

---

[1]The available water supply used in this analysis is the discharge measured in the canal as it arrived at the command area. A more appropriate supply would actually be the flow in the stream at the diversion structure. It was not, however, possible to measure this on a daily basis because of the nature of the topography and stream discharge.

[2]This differs somewhat from Yoder's (1986) RWSA, which is the relative water supply actually measured for the observed management practices. These practices have an effect on the rate of seepage and percolation and, thus, the demand. The demand in this analysis is the seasonal average of what Yoder calculated in computing a relative water supply theoretical, RWST.

[3]The hydraulic conductivity of a saturated soil is a function of physical and chemical properties of the soil such as porosity, structure, grain shape, organic matter content, exchangeable sodium percentage and total concentration of salts (Yoder, 1986).

the season, and this range was found in all three sites where measurements were taken.[4] On the basis of these measurements, an average demand of 4 liters/sec (approximately 35 ha-mm/ha/day) was assumed for the calculation. Since what is of interest here is a comparison of relative water supply among systems with the same demand, the actual magnitude of the demand is not critical.

Table 5.3 presents the GRWS and the corresponding expected level of organizational structure for the sample systems according to the hypothesis. The supply term of the GRWS ratio is the total amount of irrigation supplied to the command area over a 98-day period--from after the seedlings were transplanted until the farmers dried their fields for the harvest.[5] Compared to data from the Philippines (Valera and Wickham, 1974) and Indonesia (Odh, 1982), this demand is extremely high. However, seepage and percolation measurements in all the research sites were consistently high. Farmers applied water at this rate and even higher, but there was no overland drainage. The porous soils on the river terraces where the water table is far below the surface require very high rates of water application to maintain continuous standing water in the fields. The Department of Irrigation, Hydrology, and Meteorology of Nepal estimates that a water duty of 4 to 5 liters/second/hectare is required for hill irrigation systems.

---

[4]Regular water measurements were not taken in Majuwa because the water supply was so abundant. There is no reason to think that the soil characteristics were significantly different there.

[5]Beginning the calculation after transplanting ignores the water needed for land preparation. This does not seriously affect the analysis because land preparation in these systems is accomplished in one day using little water compared to the Philippines where the water utilized for land preparation may account for more than 30 percent of the seasonal requirement (Valera and Wickham, 1974).

Table 5.3 Expected Organizational Structure vs. Water Supply/Hydraulic Command Area

Organization	Hydraulic Command Area (Ha.)	Water Supply/ Command Area (GRWS)		Expected Level of Organizational Structure	Rank[a]
Tallo Kulo, Thambesi	50.0	0.28	Very Low	Very High	1
Thulo Kulo, Chherlung	41.7	0.82	Medium	Medium	4
Tallo Kulo, Chherlung	23.9	0.67	Low	High	3
Raj Kulo, Argali	102.9	0.60	Low	High	2
Kanchi Kulo, Argali	14.2	1.02	Medium	Medium	5
Saili Kulo, Argali	14.9	1.26	High	Low	7
Maili Kulo, Argali	15.8	1.18	High	Low	6
Damgha Kulo, Majuwa	27.5	1.70	Very High	Very Low	8

[a]Predicted rank of level of organizational structure (1 = highest).

In Table 5.3, the categorization of the GRWS as very low, low, medium, high, and very high was assigned by grouping figures that were close to each other. By the hypothesis that the level of organizational structure would be inversely proportional to GRWS, the expected level of organizational structure was generated. For example, a GRWS that is "very low" would predict a "very high" level of organizational structure, and a "high" GRWS, a "low" level of organizational structure.

While the water supply relative to the hydraulic command area may be scarce, yielding a low gross water duty and a high expected level of organizational structure, the net relative water supply (NRWS) may not be low. This is because the area actually irrigated may be significantly less than the hydraulic command area. Table 5.4 compares the hydraulic command area with the area actually irrigated by the systems.

Table 5.4 Hydraulic Command Area vs. Area Actually Irrigated

System	Hydraulic Command Area (ha)	Area Actually Irrigated (ha)	Percent Irrigated
Tallo Kulo, Thambesi	50.0	22.6	45
Thulo Kulo, Chherlung	41.7	34.8	83
Tallo Kulo, Chherlung	23.9	17.9	75
Raj Kulo, Argali	102.9	46.5	45
Kanchi Kulo, Argali	14.2[a]	10.7[a]	75
Saili Kulo, Argali	14.9	14.9	100
Maili Kulo, Argali	15.8	15.8	100
Damgha Kulo, Majuwa	27.5	27.5	100

[a]Excludes a small amount of area irrigated by a secondary above the flume which measured the flow in the main canal.

The Saili Kulo and Maili Kulo systems of Argali and Damgha Kulo system of Majuwa are land-constrained systems, i.e., the irrigated areas are bordered by other irrigation systems, major rivers, and drains which render irrigation of additional land infeasible. The other systems are water-constrained, i.e., there is land in the hydraulic command area that is not being irrigated but to which it would be feasible to deliver water. Table 5.5 presents the expected level of organizational structure as a function of the water supply relative to the area actually irrigated, the NRWS.

Table 5.5 Expected Organizational Structure vs. Water Supply/Area Actually Irrigated (NRWS)

Organization	Area Irrigated	Water Supply/ Area Irrigated (NRWS)		Expected Level of Organizational Structure	Rank[a]
Tallo Kulo, Thambesi	22.6	0.61	Very Low	Very High	1
Thulo Kulo, Chherlung	34.8	0.99	Medium	Medium	3
Tallo Kulo, Chherlung	17.9	0.90	Medium	Medium	2
Raj Kulo, Argali	46.5	1.34	High	Low	6
Kanchi Kulo, Argali	10.7	1.35	High	Low	7
Saili Kulo, Argali	14.9	1.26	High	Low	5
Maili Kulo, Argali	15.8	1.18	High	Low	4
Damgha Kulo, Majuwa	27.5	1.75	Very High	Very Low	8

[a]Rank of level of organizational structure predicted by NRWS (1 = highest).

In comparing Tables 5.3 and 5.5, one notes several differences. The GRWS in the Raj Kulo of Argali in Table 5.3 is low, and the expected level of organizational structure is high. The GRWS and expected level of organizational structure of Argali's Kanchi Kulo are medium. In Table 5.5, however, the NRWS in these two irrigation systems is high and the expected level of organizational structure is low. The conclusion that one might draw from a situation like this, where there is additional area that could be irrigated but the irrigation organization is using a large amount of water on a limited area, is that the organization is weak and ineffective. It is not using the scarce water resource efficiently but is wasting it.

It is true that the organization does not appear to be using the water efficiently.[6] But this is not because the organizations are loosely structured

[6]It is important to introduce a caveat here. The use of water was only measured during one year in these systems. It may be that in some years with less rainfall the organization must work very hard to irrigate the area that we observed and that water-use efficiency would be much higher. From comparison of annual rainfall data from a meteorological station nearby, the rainfall in the year we observed was just about average.

or ineffective. On the contrary, both are highly structured and effective. The Raj Kulo organization is one of the most highly developed and formal of the organizations studied, with numerous designated roles, regular meetings, and written records including a constitution, minutes of meetings, accounts, and members' attendance at work. It is not the ineffectiveness of the organization which accounts for the high water supply relative to the area actually irrigated. The Kanchi Kulo organization is similar, though being smaller has fewer designated roles and no written constitution. Rather the organizations are able, through the established tradition of water rights, to effectively restrict access to the water from the system. Thus, only a portion of the hydraulic command area receives irrigation for monsoon rice even though, with more intensive management of distribution, there is sufficient water to irrigate a larger area. The institution of water rights and its impact on the efficiency of water use will be discussed and analyzed in the following two chapters.

By a comparison of the water supply per hydraulic command area (GRWS) and water supply per area actually irrigated (NRWS) for the different irrigation systems, we have arrived at different expected levels of organizational structure as presented in Tables 5.3 and 5.5. Table 5.6 compares the expected levels of organizational structure from Tables 5.3 and 5.5 with the levels actually observed.

Table 5.6 Expected and Observed Levels of Organizational Structure

Organization	Expected Structure According to: Water Supply/ Command Area (GRWS)	Water Supply/ Irrigated Area (NRWS)	Observed Level of Organizational Structure
Tallo Kulo, Thambesi	Very High	Very High	Very Low
Thulo Kulo, Chherlung	Medium	Medium	Very High
Tallo Kulo, Chherlung	High	Medium	Very High
Raj Kulo, Argali	High	Low	Very High
Kanchi Kulo, Argali	Medium	Low	Medium
Saili Kulo, Argali	Low	Low	Medium
Maili Kulo, Argali	Low	Low	Medium
Damgha Kulo, Majuwa	Very Low	Very Low	Low

Even though there is increasing management intensity observed for distribution with a lower net relative water supply as was shown in Chapter 4, this seems to have little impact on the overall structure of the management organizations, as the differences between the expected and observed levels of management structure shown in Table 5.6 demonstrate. In the Tallo Kulo system of Thambesi, the GRWS and the NRWS are very low, leading us to expect a very high level of management intensity and organizational structure. But the organization, consisting of 55 farmers, has no designated officers or functionaries, holds no regularly scheduled meetings, does not have established sanctions for infractions, and maintains no written records. It does distribute water by rotation throughout the monsoon rice season, an intensive level of management for distribution, but this has not resulted in a higher degree of organizational structure.

The Thulo Kulo system of Chherlung has a medium GRWS and NRWS but exhibits the highest level of management intensity and organizational structure among the sample systems. There is significant differentiation of function among the 105 members with an elected leader (mukhiya), secretary (sachiv), and management committee. The organization holds regularly scheduled meetings for conducting business and making decisions at which attendance is mandatory. Minutes are recorded of the meetings, and written records of members' water allocations and attendance at work, as well as accounts of the organization, are maintained. Fines are imposed for missing work. Water distribution during the monsoon rice season is by continuous flow over saachos into secondary canals and by continuous flow or rotation below the saachos depending on the adequacy of the supply in a given secondary.

The GRWS of the Raj Kulo system in Argali predicts a high level of management intensity and organizational structure, while the NRWS predicts a low level. The observed level of organizational structure and management was among the highest. The Raj Kulo organization has a written constitution and a number of elected functionaries. It maintains written records of the 158 members' attendance at work and their water allocations, the organization's accounts, and minutes of meetings which are signed by all members present. Sanctions for missing work or stealing water are set and enforced. Regular and extraordinary meetings of the organization are held to discuss plans, elect officers, present financial reports, and make policy decisions. Sometimes special committees are appointed to develop proposals for consideration or to carry out specific tasks. The water flow level allows for continuous-flow distribution by proportioning weirs throughout the monsoon rice season.

The Maili, Saili, and Kanchi Kulo organizations of Argali, with 72, 51, and 28 members respectively, have similar management organizations. They all have elected officers; hold regular meetings; and maintain written minutes, records of members' attendance at work, and accounts. They establish and enforce sanctions for missing work. Maili and Saili Kulo systems are land-constrained, i.e., there is no additional area that could be irrigated and the area irrigated equals the hydraulic command area. The GRWS and NRWS are identical and predict a low level of management and organizational structure, whereas the observed organizational structure is relatively high. In the Kanchi Kulo system, the area irrigated is constrained by the tradition of water rights. Thus while the GRWS predicts a medium level of management, the NRWS predicts a low level of organizational structure. Here again, the observed level of structure is relatively high. With the exception of a part of the Kanchi Kulo area which practiced rotational distribution in the latter half of the season when the supply was diminished, distribution in the three systems during the monsoon rice season is by continuous flow through proportioning weirs.

The Damgha Kulo system in Majuwa is land constrained, and the water supply relative to the hydraulic command area is abundant. This predicts a very low level of organizational structure. The observed level of organizational structure was low, although there is more structure than in the Thambesi system. There are no elected officers in the organization. Functioning as a de facto leader is one of the members who has been awarded a contract for carrying out all of the maintenance on the main canal. Since members pay him according to their water allocations, he keeps a record of the allocation of each of the 111 members and of their payments. Other than this there are no written records. There are two regular meetings of the organization during the year. The water supply is plentiful enough to allow for continuous-flow distribution for monsoon rice without measurement below the secondaries.

5.2 Alternative Hypotheses

The above discussion has explained the hypothesis that the level of organizational structure is inversely correlated with the relative water supply and found that it does not hold for a number of the systems that were studied. The very low level of organizational structure in the Tallo Kulo organization in Thambesi does not follow from the very low gross relative water supply and net relative water supply. In Argali, the high net relative water supplies of the four systems do not predict the relatively high level of organizational structure. This is particularly true of the Raj Kulo organization.

5.2.1 Weak at the Extremes, Strong in the Middle

These results forced us to look for other explanations for the organizational structure. Since the level of organization in Damgha Kulo in Majuwa with a very high GRWS and NRWS and that of Tallo Kulo in Thambesi with a very low GRWS and NRWS were similar, we hypothesized that the relationship of management intensity and organizational structure to the relative water supply could be described by an inverted U-shaped function as in Figure 5.1.

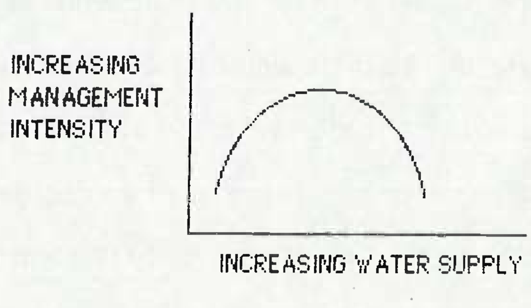

Figure 5.1 Management Intensity vs. Water Supply: An Hypothesis

At the extremes where water is either very scarce or extremely abundant, increased management efforts through a stronger organization are either unproductive or unnecessary. The maximum returns to and, thus, incentives for organized group activity may be in cases of intermediate water supplies. This type of community response function was suggested by Uphoff, Wickramasinghe, and Wijayaratna (1981) in analyzing incentives for farmers' participation in system management.

By this hypothesis it would be expected that the Tallo Kulo system in Thambesi and the Damgha Kulo system in Majuwa would both have very low levels of organizational structure, as they do. The rank order predicted by this hypothesis and the actual ranking from Table 5.1 are presented in Table 5.7.

Table 5.7 Rank Order of Levels of Organizational Structure Predicted by Inverted-U Hypothesis

System	Distance from Mean NRWS[a]	Predicted Rank	Observed Rank
Tallo Kulo, Thambesi	-.57	7	8
Thulo Kulo, Chherlung	-.19	5	1
Tallo Kulo, Chherlung	-.28	6	2
Raj Kulo, Argali	.16	3	2
Kanchi Kulo, Argali	.17	4	5
Saili Kulo, Argali	.08	2	4
Maili Kulo, Argali	.00	1	5
Damgha Kulo, Majuwa	.57	7	7

[a]Observed NRWS of the system minus mean NRWS of all eight systems.

The organizations which are significantly misranked are the Maili Kulo of Argali and the two organizations in Chherlung. It could be that the midpoint between the two extremes of Majuwa and Thambesi does not really define the point at which the maximum incentives for strong organization are to be found. The maximum of the inverted U may be closer to the NRWS of the Thulo Kulo organization in Chherlung than to that of the Maili Kulo of Argali, which happened to be the midpoint between the observed extremes.

5.2.2 Organization to Restrict Access to the Water Resource

The high organizational structure of both the Raj Kulo and Kanchi Kulo might be due to the fact that they are irrigating less than the entire command area, yet operating at a relatively high NRWS. A plausible argument could be made that systems with a relatively high NRWS and a low GRWS will need to have a strong organization to be able to restrict the access to water since there is additional land that could be irrigated. One would think that since water is such a valuable resource, farmers whose fields could be irrigated would be clamoring to force organizations like the Raj Kulo and Kanchi Kulo to allow them access to the water for irrigating monsoon rice.

Surprisingly, very little of this type of sentiment was encountered. Several factors could explain this. First, the systems are very old, and the principle of water rights may be so well established that people do not think of questioning it. Second, the information obtained concerning the development of these systems suggests that the relatively high NRWS may be a fairly recent phenomenon. At least in the case of the Raj Kulo, improvements over the past two to three decades are said to have greatly increased the volume and reliability of the supply. Pressure to allow greater access to the water may yet develop as farmers without a water allocation realize over a period of time that there is excess water in the system. Finally, the fact that farmers in the command area are permitted to use the system to irrigate wheat and maize in the winter and spring may remove some of the pressure to allow wider access to the water in the monsoon season. Nonetheless, the fact that the irrigated area is being restricted may contribute to the strength and level of organizational structure observed. This would not, however, explain why the Saili and Maili Kulo organizations, both with fairly high values for NRWS and GRWS, but no additional land to irrigate, have organizational structures similar to that of the Kanchi Kulo.

5.2.3 Organizational Structure as a Function of Size

An argument could be made that size, especially the number of members, would be an important variable explaining the level of organizational structure. Organizational theory says that, in general, ceteris paribus, an organization with a large number of members will be more formally structured than one with fewer members. While this may contribute to the organizational structure, it does not explain much of the variation observed. The Damgha Kulo organization with 111 members is the second largest organization, yet has a low level of organizational structure. The Kanchi Kulo organization of Argali with only 28 members is considerably smaller than all the other organizations. However, it has a relatively highly structured organization, much higher than that of the Tallo Kulo of Thambesi, with 55 members, and the Damgha Kulo organization. The number of members in each organization and the ranking of the relative levels of organizational structure predicted by this hypothesis are given in Table 5.8.

Table 5.8 Number of Organization Members and Predicted Ranking of Level of Structure

System	Members	Predicted Rank	Observed Rank
Tallo Kulo, Tambesi	55	6	8
Thulo Kulo, Chherlung	105	3	1
Tallo Kulo, Chherlung	61	5	2
Raj Kulo, Argali	158	1	2
Kanchi Kulo, Argali	28	8	5
Saili Kulo, Argali	51	7	4
Maili Kulo, Argali	72	4	5
Damgha Kulo, Majuwa	111	2	7

5.2.4 Organization to Mobilize Resources for System Maintenance - A Tentative Hypothesis

Implicit in the hypothesis that the level of organizational structure is inversely correlated with the water supply is the assumption that the farmers' management and organizational structure are primarily for the distribution of the water. The activity of water distribution is assumed to be the dominant function of the organization and determinant of its structure. This may be true of farmer organizations within large irrigation systems which are jointly managed by an irrigation bureaucracy and farmer organizations. The bureaucracy may carry out all activities required to deliver water to a certain level within the system where it becomes the responsibility of the farmers' water-user organization to distribute it among the fields.

But there are other activities involved in the operation of an irrigation system, and in different environments different ones may be more determinative of the organizational structure. It was after doing a rapid appraisal of irrigation systems in Khairini in Gulmi District that an alternative hypothesis was developed that seems to better explain the organizational structure of the farmer-managed irrigation systems in the hills of Nepal. There are several irrigation organizations in Khairini, and all have an extremely abundant water supply. The organizations have almost no formal structure, much like the Tallo Kulo system in Thambesi which, however, has a very scarce supply. One of them does have a list of the members. Several years previous when the canal had been badly damaged by a flood, a list of the members had been compiled and attendance taken during the repair work. In thinking about this and reflecting on our observations of the other systems' organizations, we concluded that the mobilization of labor for maintenance of the system was a key activity in this environment and the factor which was most influential in determining the organizational structure. The greater the amount of labor that needed to be mobilized to maintain the headworks and main canal to capture and convey water to the command area, the more highly structured and formal was the organization. This was found to be true irrespective of the amount of supply available. In this environment of monsoon flood streams and unstable hill slopes, organization is more important for water acquisition than for water distribution.

5.3 Cultural Ecology and Irrigation Organization

The hypotheses relating the level of organizational structure (1) to the relative water supply and (2) to the need to mobilize resources to maintain the system, view the organization as an adaptation of a group of people to their environment. The physical environment places certain constraints and demands on the irrigation organization. The theory of cultural ecology has examined man's adaptive processes and has seen irrigated agriculture as one of society's adaptations with important implications for social organization. "Cultural ecology is the study of the processes by which a society adapts to its environment" (Steward and Murphy, 1977: 44). Social organization is viewed as an adaptive response to the environment. This adaptive response may be filtered by the culture. "Relevant environmental features depend upon the culture. The simpler cultures are more directly conditioned by the environment than advanced ones" (Steward, 1973:40). The central variable in cultural ecology is the organization of work (Steward and Murphy, 1977). According to Murphy,

> the theory and method of culture ecology posit a relationship between the resources of the environment, the tools and knowledge available to exploit them, and the patterns of work necessary to bring the technology to bear upon the resources. The organization of work, in turn, is hypothesized as having a determinant effect upon other social institutions and practices. The key element in the equation is not the environment, nor is it the culture. Rather, it is the process of work in the fullest sense: the division of labor and the organization, timing, cycling, and management of human work in pursuit of subsistence (Steward and Murphy, 1977:22).

Using a cultural ecology approach, it has been argued that the amount of work that needs to be accomplished for irrigation is determinative of the social organization. Wittfogel's Oriental Despotism (1957) is probably the most elaborate and controversial statement of this hypothesis, termed the "hydraulic hypothesis." The essence of Wittfogel's argument focuses on the nature of the tasks in large-scale irrigation. Dams must be built, canals dug and periodically cleaned, and water, since it is a scarce commodity, must be allocated. Since the system serves more than one community, cooperative activity is required which necessitates certain organizational features.

> If irrigation farming depends on the effective handling of a major supply of water, the distinctive quality of water--its tendency to gather in bulk--becomes institutionally decisive. A large quantity of water can be channeled and kept within bounds only by the use of mass labor; and this mass labor must be coordinated, disciplined and led. Thus a number of farmers eager to conquer arid lowlands and plains are forced to invoke the organizational devices which--on the basis of premachine technology--offer the one chance of success: they must work in

cooperation with their fellows and subordinate themselves to a directing authority (emphasis added) (Wittfogel, 1957:18).

He then argues that these organizational needs of the irrigation system "give those persons in the irrigated society who occupy crucial role synapses in the irrigation system, expansive powers in other domains of social life" (Hunt and Hunt, 1974:27). In Wittfogel's words,

> The effective management of these works involves an organizational web which covers either the whole, or at least the dynamic core of the country's population. In consequence those who control this network are uniquely prepared to wield supreme political power (1957:27).

Wittfogel's hypothesis deals with the relationship of the organizational requirements of massive irrigation systems to the creation of powerful, centralized states, a situation and problem very different from the small-scale, irrigation systems in the hills of Nepal and the determinants of their organizational structure. As such his arguments are not necessarily applicable and will not be presented in detail.[7] However, it is clear that (1) even small-scale irrigation, in nearly all cases, requires some organization, and (2) the structure of this organization will be to some extent an adaptation to the environmental conditions of the irrigation system. According to Netting (1974:33) "hierarchical authority may be a necessity only when (a) the scope of irrigation works requires for its construction and

---

[7]Witfogel's thesis, first advanced in the 1930s, generated considerable controversy, and many scholars (Adams, 1974; Leach, 1959; Palerm, 1955; and Mitchell, 1973.) have brought archeological and historical evidence from the different "irrigation civilizations" (Egypt, Mesopotamia, China, Mesoamerica, Sri Lanka, and the Central Andes) to bear on the hypothesis that irrigation has been the primary causative factor in the development of highly centralized bureaucratic states. Most of their arguments have to do with evidence (1) of the existence of a state organization prior to the construction of large-scale irrigation systems or (2) that large-scale systems were constructed under a decentralized system much like European feudalism rather than by a powerful, central despot.

maintenance greater capital investment or technological skill than can be provided by individual cultivators or local associations, or (b) when a growing scarcity of water threatens disorder and conflict which will seriously reduce the utility of the system." He is referring here to the need for involvement of some extra-local authority in the irrigation organization, but it can also be argued that the same two factors, i.e., the amount of resources needed for construction and maintenance and the relative water supply, will have an impact on the structure of the local irrigation management organization even if it has no articulation with any higher authority.

There is evidence from farmer-managed irrigation systems in other locations of the importance of the function of resource mobilization for water acquisition in the structure of the organization. Moerman (1968) describes a system in northern Thailand where the major duty of the leader of the organization is the mobilization of labor and materials for the annual repair of the diversion structure. In a system in Burma described by Nash (1965), the leader's role is organized around the work of maintaining the canal.

Both the relative water supply and the need to mobilize resources for the construction and maintenance of the irrigation systems are, at least conceptually, important factors determining the structure of the management organizations of farmer-managed irrigation systems. The affect of scarcity of supply on the structure of the farmer-managed irrigation organizations has already been analyzed, and we have seen that, for the systems studied in the hills of Nepal, the relative water supply does not have the expected impact on the structure of the irrigation management organizations. The irrigation organizations will now be analyzed with respect to the influence on the organizational structure of the need to mobilize resources, particularly labor, for water acquisition.

5.4 Analysis of Resource Mobilization and Organizational Structure in the Systems Studied

In the small-scale, farmer-managed irrigation systems in the hill region of Nepal, the activity of water acquisition often requires so many resources that the organizational needs for carrying out this activity dominate the structure of the organization. The critical organizational activity in many of the systems is that of resource mobilization for maintenance of the intake and main canal, and the structure of the organization reflects this. Many organizations do major annual maintenance in June prior to transplantation of the monsoon rice crop. During the monsoon season, one or two men patrol the main canal every day to repair small leaks in the intake and canal and to give an early warning if major damage, such as a landslide, has occurred requiring emergency maintenance work by all the members of the system.

If members of an irrigation organization have to invest a significant amount of labor and, sometimes, cash in order to acquire water, they will want to be sure that everyone who is benefiting is contributing his fair share. Hence, in organizations that must mobilize a large amount of resources, written attendance records, sanctions for missing work, and audited accounts were found. The rules that organizations make and record and the minutes of meetings tend to focus on the issues surrounding the mobilization of resources, e.g., how much labor and cash members must contribute, the fines for not attending work, and circumstances under which one is excused from work. The main functions of the elected officers of the organizations are to organize and supervise the maintenance work on the system, keep accurate records of members' contributions, and enforce sanctions for failure to contribute as required. This is the case in Argali and Chherlung where the canals are from two to six kilometers long, requiring many man-days of labor for maintenance prior to and during the monsoon season.

On the other hand, the system in Thambesi has a main canal that is less than 100 meters long and can be cleaned in one day without all of the members working. This has resulted in an organization which is less concerned that an accurate record of members' contributions is maintained and proportional contribution by all members enforced. The Tallo Kulo organization in Thambesi does not keep records of members' attendance at work, imposes no sanctions for being absent, maintains no written rules nor minutes of meetings, and keeps no accounts. The organization has no officers or designated functionaries.

Further evidence of the importance of labor mobilization for maintenance was given by the secretary (bhaidar) of the Raj Kulo in Argali. In describing the operation of the Raj Kulo, he began by saying that on a day of ordinary maintenance work, 22 workers were required from Ranuwa and 22 from Rabidas.[8] Because the two areas are responsible to furnish the same number of laborers, they each are entitled to half of the water even though the area irrigated in the two areas is no longer equal. The main saacho divides the canal flow in half with one secondary serving Ranuwa and the other Rabidas. Later he said that individual farmers have to contribute labor based on their water allocation. The fact that he began his description of the system operation and structure by stating the number of maintenance workers required from the different parts of the system is an indication of

---

[8]Ranuwa and Rabidas are two hamlets in Argali, and most of the farmers with fields in the upper part of the system live in Ranuwa while most with fields in the lower part live in Rabidas.

the primacy of the activity of resource mobilization for water acquisition in the structure and functioning of the organization.

The records maintained by a number of the organizations proved to be a good source of data concerning resource mobilization, particularly labor, over the years. The number of years of data which were copied and tabulated ranged from 3 for the Thulo Kulo in Chherlung to 18 for the Raj Kulo in Argali. Table 5.9 presents the average number of man-days of labor mobilized by the organizations.

Table 5.9 Annual Labor Mobilization

Organization	Number Years Labor Records	Total Man-days Labor Mobilized
Tallo Kulo, Thambesi	a	370
Thulo Kulo, Chherlung	3	2440
Tallo Kulo, Chherlung	7	1979
Raj Kulo, Argali	18	1909
Kanchi Kulo, Argali	5	608
Saili Kulo, Argali	4	1208
Maili Kulo, Argali	11	827
Damgha Kulo, Majuwa	b	440

a. Estimated by extrapolating from sample farmers' responses to question about how many days they worked on the system.
b. Estimated by dividing the value of the maintenance contract by the daily wage rate.

The labor data for the systems in Chherlung and Argali were copied from the labor attendance records of the respective irrigation organizations. No written records of labor mobilization are maintained by the Tallo Kulo system of Thambesi and Damgha Kulo system of Majuwa. An estimate of the total labor mobilized in Thambesi was made by taking the average number of days that the sample farmers reported they had worked on the system and extrapolating for the total membership. Comparing this figure with the amount that was reported in a rapid appraisal that was conducted of Thambesi at the beginning of the research period and in informal discussions with farmers concerning the amount of maintenance labor required leads to a conclusion that the extrapolated figure of 370 likely overestimates the number of man-days of labor mobilized for maintenance.[9]

In addition to the labor mobilized for maintenance of the systems, all of the organizations in Chherlung and Argali have, in recent years, assessed cash contributions from their members to make improvements to their respective intakes and main canals. Keeping account of these contributions and the expenditures also requires more organizational structure. The Damgha Kulo system in Majuwa has the same need to record accounts since the maintenance is given out on contract. Specific contracts have also been given out several different times for tunnel construction on the main canal of the Damgha Kulo system. The Tallo Kulo organization in Thambesi has not raised any cash from its members.

Table 5.10 relates the amount of resources (man-days of labor) mobilized to the predicted and actual degree of organizational structure and management intensity.

[9]They probably reported the number of times they did some work on the system, and likely it was often only for a few hours.

Table 5.10 Resource Mobilization vs. Level of Organizational Structure

Organization	Total Man-days of Labor Mobilized		Organizational Structure Expected	Rank	Observed	Rank
Tallo Kulo, Thambesi	370	Very Low	Very Low	8	Very Low	8
Thulo Kulo, Chherlung	2438	Very High	Very High	1	Very High	1
Tallo Kulo, Chherlung	1979	Very High	Very High	2	Very High	2
Raj Kulo, Argali	1909	Very High	Very High	3	Very High	2
Kanchi Kulo, Argali	608	Medium	Medium	6	Medium	5
Saili Kulo, Argali	1208	High	High	4	Medium	4
Maili Kulo, Argali	827	High	High	5	Medium	5
Damgha Kulo, Majuwa	440	Low	Low	7	Low	7

From Table 5.10, it appears that the level of organizational structure is fairly directly correlated with the total amount of labor that must be mobilized by a system to acquire water, i.e., to maintain the intake and conveyance canal so that water can be delivered to the command area.

It would seem that one should control for the scale of activity relative to command area. The amount of labor per hectare and labor per member are, thus, other variables which could be examined. Table 5.11 presents an analysis of the predicted level of organizational structure based on the labor required per hectare and per member for water acquisition.

Table 5.11 Organizational Structure vs. Labor per Hectare and Labor per Member

Organization	Man days/ Ha.	Predicted Rank	Man days/ Member	Predicted Rank	Observed Rank
Tallo Kulo, Thambesi	16	7	7	7	8
Thulo Kulo, Chherlung	70	3	23	3	1
Tallo Kulo, Chherlung	111	1	32	1	2
Raj Kulo, Argali	41	6	12	5	2
Kanchi Kulo, Argali	54	4	22	4	5
Saili Kulo, Argali	81	2	24	2	4
Maili Kulo, Argali	52	5	11	6	5
Damgha Kulo, Majuwa	16	8	4	8	7

Neither man-days of labor per hectare nor man-days of labor per member seems to be quite as good as total labor for predicting the level of organizational structure in these systems, although both are better than water supply relative to the hydraulic command area (GRWS) or relative to the area actually irrigated (NRWS). Neither variable predicts the very high level of organizational structure observed in the Raj Kulo system of Argali; both predict a medium level. The prediction according to labor/hectare is also off by one level for Thambesi, Thulo Kulo of Chherlung, Kanchi and Maili Kulos of Argali, and Damgha Kulo of Majuwa. Man-days/member mispredicts Thambesi, Thulo Kulo of Chherlung, Maili Kulo of Argali, and Damgha Kulo of Majuwa by one level in addition to the misprediction of the organization of the Raj Kulo organization. However, since the classification of levels is somewhat subjective, these predictions are also quite good.

5.5 Statistical Test of the Ranking of Organizational Structure by Different Hypotheses

A statistical procedure which can be used to compare the rankings of the predicted levels of organizational structure with the actually observed level is the Spearman rank-correlation coefficient. It is one of the best-known non-parametric statistical methods and is used to compare two rankings of a variable to determine whether they are statistically different (Snedecor and Cochran, 1967:194). This statistic was calculated for the rankings predicted by each hypothesis, comparing the actually observed ranking of the levels of organizational structure from Table. 5.2 with the predicted rankings. Table 5.12 reviews the rankings and presents the Spearman rank-correlation statistic for the ranking given by each hypothesis.

Table 5.12 Ranking of Systems According to Predicted Level of Organizational Structure

	Rankings[a]								
System	A	B	C	D	E	F	G	H	I
Tallo Kulo, Thambesi	8	1	1	7.5	2	6	8	7	7
Thulo Kulo, Chherlung	1	4	3	5	5	3	1	3	3
Tallo Kulo, Chherlung	2.5	3	2	6	3	5	2	1	1
Raj Kulo, Argali	2.5	2	6	3	1	1	3	6	5
Kanchi Kulo, Argali	5.5	5	7	4	4	8	6	4	4
Saili Kulo, Argali	4	7	5	2	7	7	4	2	2
Maili Kulo, Argali	5.5	6	4	1	7	4	5	5	6
Damgha Kulo, Majuwa	7	8	8	7.5	7	2	7	8	8
Rank correlation coefficient	–	.18	.14	.34	.19	.30	.98[b]	.68	.75[c]

[a]Ranking variable or hypothesis: A – Actual ranking for level of organizational structure
B – GRWS
C – NRWS
D – Inverted U-shape (weak at extremes, strong in middle)
E – Percent of command area irrigated
F – Number of members in organization
G – Total maintenance labor per year
H – Maintenance labor per hectare per year
I – Maintenance labor per member per year

[b]Significant at 1% level
[c]Significant at 5% level

The ranking according to the total amount of labor mobilized for maintenance of the system is the one most similar to the actually observed ranking. The null hypothesis that they are uncorrelated is rejected at the 1% level. Annual maintenance labor per member is significant at the 5% level, and labor per hectare is the next best predictor. The two relative water supply variables are the poorest predictors for this sample of systems. The inverted U-shape (little organizational structure at the extremes of relative water supply and more in the middle) may be a better predictor than indicated by the test. The ranking was assigned by determining the mean NRWS of the two extremes of the eight systems and ranking the systems from 1 to 8 as their NRWS was farther from the mean. This does not take into consideration how far they are from the mean, i.e., a gap of .01 between two would be weighted the same as a gap of .2 if that were the gap between two that were next to each other. Also, it could be that the mean of the extremes of the observed relative water supplies is not the value that would give the highest level of structure. In other words the observations from the eight systems might be skewed toward one side or the other of the middle value that would result in a high level of organizational structure.

5.6 Conclusion

An irrigation organization has a number of different tasks and activities which it must accomplish to make effective use of the water resource in agricultural production. Different environments render different activities more or less important, and the nature of the activity and its relative importance will determine, to some degree, the organizational requirements of a system. These, in turn, will have an impact on the structure of the organization.

The physical activities directly related to water in an irrigation system are: acquisition, distribution, and drainage. In the extremely well-drained soils of the river terraces in Nepal where the systems studied are located, drainage is not a significant concern of the organizations. Both acquisition and distribution are important. A more intensive technology and management to achieve a greater degree of control over the distribution of water were observed where the water supply was scarce relative to the area irrigated. Organizations installed technology (saachos) or adopted management practices (rotational distribution or distribution by contract) which enabled them to distribute the water more efficiently and equitably. However, this activity did not appear to have nearly as much of an impact on the structure of the organizations as did the activity of water acquisition.

Organizations which must mobilize large amounts of resources, particularly labor, to maintain the system to acquire water, irrespective of the amount of water delivered, are much more highly structured than those which require relatively few resources to keep the water flowing. Both of these factors, the water supply relative to area irrigated (NRWS) and the amount of resources that must be mobilized for water acquisition, certainly affect the nature of the organization, but the organizational requirements for mobilizing resources to maintain the system dominate the structure of the organizations in this environment.

The labor requirement for rotational distribution can be considerable although, with the exception of the Tallo Kulo in Thambesi, it does not exceed the labor needed for water acquisition. Even though a significant amount of labor may be required for distribution, it does not have the same effect on the organization as the labor for acquiring the water. This is because labor for distribution is essentially an individual affair.[10] The organization as a whole does not suffer if an individual is absent when it is his turn to receive water--only he does. However, if people fail to participate in maintaining the system, everyone will suffer to some extent from a shortage of water.

All of the discussion and analysis above has been based on the organizations' activities and structure for the monsoon rice season. It is interesting to compare organizations in this season with their activities and structure in the winter season. The Raj Kulo of Argali is a particularly interesting case. In the winter, the water supply in the stream is much less than during the monsoon, yet the area that is irrigated is over 100 hectares compared to 47 hectares in the monsoon season. Farmers who do not have access to water for irrigating rice are permitted to irrigate wheat in the winter. This can be done because irrigation of wheat requires much less water than irrigation of rice.

The intensity of management and the level of organizational structure is much lower in the Raj Kulo system during the winter than in the monsoon season. There is no systematic procedure for coordinating water distribution among all the farmers. Farmers meet at a designated place on the main canal on the day they want to irrigate, and those who are there that day decide among themselves the order of distribution. Since the water demand of the wheat crop is so much lower than that of rice, the relative water supply during this season is higher. Even more importantly, almost no maintenance is required to keep the water flowing. There is very little

---

[10]There are examples, though not observed in the systems studied, of a group of farmers working together for distribution. When it is time for the group's part of the system to receive water, some of them police the canal while others in the group irrigate.

rainfall during this season; hence, the intake is seldom destroyed by floods, and landslides which damage the canal rarely occur.

There seems to be a relationship between the need to mobilize resources to acquire water and the effectiveness of distribution of the water. Lewis (1980) compares two systems in the hills of Ilocos Norte in the Philippines. The one requires much maintenance (40 to 60 work days per member annually). It enforces fines for absence from work, and repeated offenders would be denied water. However, in the year that he observed, there were few absences, and all fines were paid. The members were satisfied that they were receiving the water to which they were entitled. In the other system, much less maintenance labor is required, but "some members regularly fail to appear for labor, and fines against them are often impossible to collect" (1980:165). Members in the tail area of this system complained of inequitable distribution, and several who were most commonly not served dropped out of the organization.

The evidence from Nepal also suggests that in systems requiring the mobilization of large amounts of resources to maintain the diversion and conveyance structures, the distribution of the water more nearly agrees with the allocation of entitlement to the water than in systems that require little effort in water acquisition. In the Tallo Kulo of Thambesi, which requires little labor for maintenance, the fields at the tail of the system suffered much more moisture stress than those at the head even though their allocation of water was said to be the same.[11] This was not true of systems in which much labor had to be invested to keep the supply flowing. In these the actual distribution of water coincided remarkably well with the allocation of water. Yoder's (1986) analysis of water distribution and stress in the Kanchi Kulo of Argali and the Thulo Kulo of Chherlung demonstrates this.

The organizations in Argali and Chherlung required the resources of all the members to acquire the water. The farmers at the head of the system could not take all they wanted, denying the tail-end farmers their share, because they were dependent for their supply on the assistance of those tail-enders in maintaining the system. This interdependence among the farmers in systems requiring a high level of resource mobilization is a key factor affecting their equitable and efficient operation. Where few resources are needed to keep the supply flowing, the head-end farmers do not have to be concerned with keeping the tail-end farmers satisfied that they are receiving their fair share of the water so that they will continue assisting in the acquisition of water. It appears that it is more difficult to have an effective organization that is primarily for distribution than it is one in which acquisition is the key activity, because the farmers do not all face the same incentives for distribution while they do for acquisition. When water is scarce, the head-end farmers have an incentive to break the rules and take

[11]As was discussed in Chapter 3 and as developed by Yoder (1986) in his Chapter 8, it is possible that there is a hierarchy of priority of water rights with those fields in the tail having the lowest priority. Even if this is the case, it does not detract from the argument that is being made here. If the system required a large amount of labor to be mobilized each year from the members, this type of priority system would likely not exist unless there was a concomitant reduction in the amount of labor the tail-end farmers had to contribute. If all farmers had to contribute the same amount per unit of area irrigated as in Argali, they would all know their water allocation (unlike the Thambesi farmers who did not) and would insist on more equal distribution of the water.

more than their allotted share of the water. Without the interdependence resulting from the need to mobilize much labor for maintenance, it is more difficult to enforce an equitable distribution of the water.

In this chapter, two new factors which affect the irrigation organizations were introduced: (1) the need to mobilize resources for water acquisition, and (2) the institution of water rights. The relationship between the amount of resources that must be mobilized to acquire water and the structure of the organizations was analyzed in this chapter. Chapters 6 and 7 will analyze the institution of property rights in water and the allocation of those rights.

CHAPTER 6: PROPERTY RIGHTS IN WATER: THE SECURITY FACTOR

In Chapter 5 it was shown that in many of the farmer-managed irrigation systems, the area actually irrigated was less than the hydraulic command area. In some cases, this was due in part to that fact that there was not enough water to irrigate effectively all of the potentially irrigible area. In other systems, irrigation of the entire hydraulic command area would have been technically feasible, or, if not the whole area, significantly more than was actually being irrigated. In both types of situations, certain specified fields had access to water while others, including some immediately adjacent to those being irrigated, did not. The fact that some people could irrigate their fields using water from the irrigation system and others could not implies that there is some legal or customary precedent by which access to water is allocated among potential users. Water is treated as an object of property in which certain people have property rights from which others are excluded. Before examining the nature of property rights in irrigation and their implications for the use of irrigation resources, it is necessary to understand more generally the concept of property.

6.1 Theory of Property Rights

Property has been a central concern, either implicitly or explicitly, of economic and social theory, as well as in the daily life of mankind, since time immemorial. The consumption and utilization of objects of property are essential to life, and the accumulation of property greatly affects the living standard of an individual and society and has been seen as one of the primary motivating factors of human behavior both individually and collectively. While in common discourse, property often refers to a physical object that can be consumed, utilized in production, or exchanged, it is a potentially confusing term with complex connotations.

In the field of economics, the institutional economists have done much to clarify the nature of property and have stressed the importance of property rights as an institution that defines the environment in which economic activity takes place. To quote John R. Commons, one of the leading institutional economists,

> The subject matter of institutional economy, distinguished from engineering and home economy, is not commodities, nor labor, nor any physical thing--it is collective action which sets the working rules for proprietary rights, duties, liberation, and exposure; and these are the present expectations of bargainers that the community will see to it that their bargaining valuations are carried out in the future by themselves and others, respecting commodities, labor, money, or anything now expected to have future usefulness and scarcity (1934:523).

Institutional economics draws a "distinction between the object of property, the rights of property, and the justification of property. . . . Property as a corporeal fact is the exclusive holding of physical things because they are scarce; rights of property are the collective securities, compulsions, liberties, and exposures that go with this exclusive holding" (Commons, 1934:168-9). Justification refers to that on which a person can base his claim to property. This justification "may be made on the general grounds of prevailing custom, combined with the specific grounds of what he has himself lawfully done in the past such as his past labor and enterprise; or his past lawful acquisition of ownership by inheritance; or his past lawful transactions in acquiring ownership by alienation of other lawful rights in ownership" (Commons, 1934:408). Three meanings of property are to be distinguished in the sense of rights. Corporeal property refers to things like land and machinery. Incorporeal property is defined as debt--the right of a creditor to compel a debtor to pay a specified sum of money. Intangible property consists of different expectations such as good-will, patent rights, the right to continue in business, the right of access to labor market, etc. (Commons, 1934).

6.1.1 Property Rights as Social Relations

Property is a social concept, and a central theme of the literature on property rights is that "property rights do not refer to relations between men and things but, rather, to the sanctioned behavioral relations among men that arise from the existence of things and pertain to their use" (Furubotn and Pejovich, 1972). As Commons said, "the term 'property' can not be defined except by defining all the activities which individuals and the community are at liberty or required to do or not to do, with reference to the object claimed as property" (1934:74). Property rights, thus, not only include privileges that one can exercise in the use of property but also include duties or responsibilities of the owner of property as well as those of other people. "The prevailing system of property rights in the community can be described, then, as the set of economic and social relations defining the position of each individual with respect to the utilization of scarce resources" (Furubotn and Pejovich, 1972:1139).

6.1.2 The Emergence of Property Rights

Property rights emerge and take on meaning as a result of scarcity. "Nothing is property that is not expected to be scarce, and everything expected to be scarce is quickly brought by collective action within the meaning of property rights" (Commons, 1934:522). According to Alchain,

> In essence, economics is the study of property rights over scarce resources....The allocation of scarce resources in a society is the assignment of rights to uses of resources...the question of economics, or of how prices should be determined, is the question of how property rights should be defined and exchanged, and on what terms (Alchain, 1967:2-3).

Demsetz (1967) has explained the development of property rights within the context of externalities. Economic processes produce both beneficial and harmful effects which, in the absence of property rights, would be referred to as externalities. Property rights emerge to internalize externalities and do so when the benefits of the internalization exceed the cost of internalization. He says that "a primary function of property rights is that of guiding incentives to achieve a greater internalization of externalities" (in Furubotn and Pejovich, 1974:32).

6.1.3 Property and Futurity

Property rights as an institution primarily have meaning with respect to the future. Economics as it deals with property rights "deals only with the Expectations of Income" (Commons, 1934:418). "Property is a set of social relationships which ties the future to the present through expectations of stabilized behavior regarding other persons and things" (Parsons, 1942). Property rights through their sanctioning of behavior are a necessary condition for investment. With property rights defined, the person who invests in the creation of property that will yield a stream of benefits in the future can have some confidence that he will be able to enjoy those benefits, or at least some of them. Without this assurance, which is a result of the structure of property rights, investment would not be forthcoming. In this vein Demsetz has written,

> Property rights are an instrument of society and derive their significance from the fact that they help a man form those

> expectations which he can reasonably hold in his dealings with others. These expectations find expression in the laws, customs, and mores of a society. An owner of property rights possesses the consent of fellow men to allow him to act in particular ways. An owner expects the community to prevent others from interfering with his actions, provided that these actions are not prohibited in the specifications of his rights (in Furubotn and Pejovich, 1972:31).

6.1.4 Enforcement of Property Rights

From this we can see that enforcement of behavior implied by a state's or society's sanctioning of property rights is crucial. Without effective enforcement of property rights, assurance is not provided to the holder of the right that he will reap the benefits to which he is ostensibly entitled through acquisition of the property right. As McKean (1974) notes, "Enforcement is crucial in shaping appropriability." This enforcement function is usually found in the legal system of the state but may also be found at a more localized level of a society in its traditional customs. As Parsons says in commenting on the significance of the property analysis in Commons' institutional economics,

> The analysis so far reveals that the power of the state, the functioning of the state, is an integral part of every business at every moment simply because the very objects of purchase and sale--property rights--are themselves created only by the unseen pressure of the state which stabilizes the wills of the participants by imposing duties upon them (1942:310).

6.1.5 Property Rights and Economic Efficiency

Extending the work of traditional microeconomics on the problem of scarcity and resource allocation and that of welfare economics on the relationship between competitive equilibrium and Pareto-efficiency, the property rights literature has emphasized and analyzed the role of property rights in these issues. To achieve efficiency under the conditions of competition and zero transactions costs, the structure of property rights must be non-attenuated (Cheung, 1974). A non-attenuated structure of property rights has the following characteristics:

1. The set of property rights is completely specified. Since property rights provide, among other things, an information system, a completely specified set of rights will reduce both ignorance and uncertainty.

2. Exclusive rights must be specified, so that all rewards and penalties accruing from an action accrue to the actor. In economic terms, all benefits and costs are internalized and private and social costs are ipso facto equal.

3. The set of property rights must be enforceable and enforced. The assurance of enforcement is essential for reducing uncertainty as to the outcomes of decisions and actions.

4. Property rights must be transferable so that property rights, like any other input, may gravitate to their highest value use. Transferability is essential to ensure achievement of the necessary marginal equalities (Randall, 1975:733).[1]

6.1.6 Forms of Ownership

Property rights are not only held by separate individuals. Demsetz (1967) distinguishes several idealized forms of property ownership. These are private ownership, communal ownership, and state ownership. Private ownership implies that society recognizes the right of the owner to exclude others from exercising the rights of ownership over the property. Communal ownership means that the community denies to the state or any individual the right to interfere with any person's exercise of communally-owned rights. State ownership implies that the state may exclude individuals from use of a right as long as it follows accepted political procedures for defining who may not use the property. Actual prevailing institutions of property rights may not fall neatly into one of the three idealized forms but may be a combination.

---

[1]The transferability of property rights in water was found to be an extremely important issue in the systems that were studied and will be analyzed separately in Chapter 7.

irrigation systems which are farmer-owned and -managed tend to have some of the attributes of both private and communal property.

From the foregoing discussion we can see that the economic literature on property rights structures is "characterized by a common emphasis on certain basic ideas concerning the interconnectedness of ownership rights, incentives, and economic behavior" (Furubotn and Pejovich, 1972). "The scope and content of property rights assignments over resources affects the way that people behave in a world of scarcity. In other words, individuals respond to economic incentives, and the pattern of incentives present at any time is influenced by the prevailing property rights structure" (Furubotn and Pejovich, 1974:1). At the same time it should not be concluded that the influence of property rights on economic outcomes is unidirectional, because the latter can influence the configuration of property rights. "Property rights are not an immutable given. The institution of property is an instrument of man designed to facilitate the accomplishment of certain ends. Thus, property rights are subject to change by man" (Ditwiler, 1975:666). The property rights approach focusses on the impact that changes in the structure of property rights will have on the choices that individuals make.

6.2 Property Rights in Irrigation

Water is one of a class of natural resources which are termed "fugitive." Fugitive resources are mobile and must be captured (reduced to possession) before they can be allocated to individuals or groups. Since such capture and allocation poses the problem of exclusion, institutional regulation of these resources tends to develop early. According to Ciriacy-Wantrup and Bishop (1975), common property institutions are the most important means of regulation of fugitive resources. Oakerson (1984) states that a "commons" is a resource that is exploited by a group, a group which has certain membership criteria. There are group rights and duties with respect to the resource. The group will try to exclude nonmembers from using the resource, and it will regulate the members' use of it.

On the basis of this description of common property, a farmer irrigation organization can be thought of as an owner and manager of common property. The water is managed by the group, with individual farmers being the ultimate consumers. There are definite criteria for membership in the group. The most common criterion is ownership of land that is irrigated by the system, but this is not so in all cases. In some systems, not all landowners are members, and in others not all members are owners of land that is irrigated. In many organizations the members are those who are farming the irrigated land whether they are owners or tenants.[2] There are organizations where landless persons also have shares in the system and are members of the organization. The rights to the water in the source are vested in the group. Irrigation organizations work vigorously to exclude nonmembers from using the water. The amount of water that members can use and when they receive it is regulated by the organization. Thus, the problems of common property resource management are ones which must be addressed by an irrigation organization and which give rise to its structure and procedures. An important problem, termed the "assurance" problem, will be discussed later.

Coward has specified three sets of objects of property that are created in the process of irrigation development. These are "the irrigated rice fields (shaped, leveled, and bunded to receive the irrigation water), the irrigation

[2]This was true in the systems that were studied; the farmers operating the irrigated land constituted the membership of the irrigation organization.

works (for acquiring, transporting, and dividing the irrigation water), and the water supply itself" (1983:4). In most places, but not all, the fields fall under the category of private property, with individuals exercising the rights of ownership. The physical irrigation works and, particularly, the water supply more often involve other forms of ownership than purely private. It is these two objects of property and the impact of the arrangement of property rights in the water and the irrigation works on the use of resources that is of interest here.

It is access to the water to enable use of it in crop production that is of primary concern to the farmer, and his interest in the irrigation works is secondary and only as a means to acquiring and distributing the water. The economist is also primarily interested in how the water is allocated as a factor of production. The focus here, thus, will be first on the institution of property rights in water and then on how ownership of the irrigation works affects the irrigation organization.

Property rights in water have emerged because of its scarcity. If it were an abundant resource like sunlight or air, the idea of a property right would be meaningless because there would be no probability of a person attempting to exclude anyone from using as much as he desired. Two important attributes of property rights for efficient development and allocation of water can be called "security" and "flexibility." Under the term security are considered the different principles according to which people can gain and lose access to water rights. Flexibility refers to the ways in which water rights can be transferred to other parties and different uses. In this chapter the interest is in the security aspect, while in Chapter 7 the importance of flexibility will be analyzed.

The relationship between security of water rights and investments in water resource development is one of the main points of emphasis when economists consider the relative merits of different systems of property rights in water (Ciriacy-Wantrup, 1964). The value of an investment in developing a water resource for an irrigation system is dependent on the future flow of benefits resulting from construction of the hydraulic works to divert and convey the water to the fields that are to be irrigated. The more uncertainty there is in the security of this stream of future benefits, the lower is the expected value of the investment. To provide incentive for investments to develop irrigation facilities, the system of property rights must provide some measure of security that the investors will be able to capture all, or at least a significant portion, of the benefits of the investment.

Uncertainty concerning the flow of benefits from an investment in an irrigation system arises from several sources. Uncertainty regarding prices of inputs and products affects the profitability of an investment in irrigation, but this uncertainty cannot be reduced through the institution of water rights and will not be addressed here. What the institution of property rights does affect is the security of the amount of water available to those who make the investment to develop an irrigation system. "Physical uncertainty," the consequence of natural fluctuations in the volume of water in the source and in the fields as a result of variations in the hydrologic cycle, is one type of variation and uncertainty. In a period of drought it may not be possible to irrigate as much land effectively as was expected when the investment was made. If there is more rain than usual in the area, rendering irrigation unnecessary for crop production, the benefits from the investment will also be reduced.

Another type of uncertainty, "tenure uncertainty," is the result of actions of other people. Both lawful and unlawful use of the water by others can reduce the supply. Unlawful use is prohibited by the system of property rights, but there must be an enforcement mechanism if the rights are to provide security for the investor. The lawful use of the water, especially when combined with the natural fluctuations in the supply in the source, may be an equally important source of uncertainty. The water rights statutes usually specify under what conditions the water can be taken away for other uses, and this determines the tenure certainty that a holder of water rights has.

In the United States, and therefore also in much of the literature, the discussion about the security aspect of water rights centers on a comparison of the "riparian" and "prior appropriation" doctrines of water rights and the ways in which they have been modified in different states' statutes. English common law first defined riparian water rights. "Every proprietor of lands on the banks of a river, has naturally an equal right to the use of the water which flows in the stream adjacent to his lands, as it was wont to run (currere solebat) without diminuation or alterations" (Meyers and Tarlock, 1971:53). This doctrine defines a collective ownership of the water by owners of the adjacent land. It excludes those who do not own land on the banks of the stream, but does not define individual ownership of the water itself. The use of water is restricted to owners of riparian land, and the right is an automatic one that is not created by use of the water nor lost or forfeited through disuse. "It is an odd sort of compromise, one that implies that water has become a scarce good, but that treats it essentially as a free one" (Nanda, 1977:142).

Strict interpretation of this riparian doctrine would forbid nearly any use of the water in a stream. Most uses result in some "diminuation or alterations." In England it was modified to recognize two classes of uses. "Natural" uses included water use for domestic or livestock purposes, and "artifical" uses were for irrigation or mechanical purposes. A person with riparian land is allowed to take all the water that he needs, even the whole stream flow, for natural uses, but for artificial uses he is limited to an amount of water that will not interfere with a similar use by downstream riparian users (Huffman, 1953). In the thirty or so states of the United States that have maintained the riparian doctrine of water rights, the notion of "reasonable use" allows for consumptive use of the water with the same categories and priorities as above.[3] The riparian doctrine has been retained mainly in regions where water is relatively plentiful and where irrigation is not necessarily essential for agriculture and, thus, not a primary use of water.

As the population of the United States moved west into regions where water supplies were much scarcer and the climate made irrigation essential for agricultural production, the riparian doctrine which vested water rights in specific land along stream banks did not enable efficient development of water resources. Most states in the western United States have abandoned the riparian doctrine in favor of the appropriation doctrine. Under the doctrine of prior appropriation, water rights belong to those individuals or groups who first put the water to beneficial use. It allows individuals to acquire water rights without having to own riparian land and permits the use of water on land without regard to its location relative to the stream from

[3]Most of the states retaining the riparian doctrine of water rights are in the more humid eastern and midwestern regions.

which it is diverted. Water rights were no longer vested in land, and water could be transported and used virtually anywhere that was technically feasible. This was particularly important because much of the most fertile land was "bench land" located a distance from the streams. The high cost of water development virtually assures that any use to which it will be put will be beneficial in an economic sense (Anderson, 1983).

The important features of the doctrine of prior appropriation can be summarized as follows (Huffman, 1953:43):

1. It gives an exclusive right to the first appropriator; and, in accordance with the doctrine of priority, the rights of later appropriators are conditional upon the prior rights of those who have preceded. (This is often referred to as the first-in-time, first-in-rights system.)

2. It makes all rights conditional upon beneficial use--as the doctrine of priority was adopted for the protection of the first settlers in time of scarcity, so the doctrine of beneficial use became a protection to later appropriators against wasteful use by those with earlier rights.

3. It permits water to be used on nonriparian lands as well as on riparian lands.

4. It permits diversion of water regardless of the diminution of the stream.

5. Continuation of the right depends upon beneficial use. The right may be lost by nonuse.

The principle of first-in-time, first-in-rights establishes senior and junior rights in a water source. In times of shortage, holders of senior rights are permitted to take their entire appropriation without regard for whether there is any left for those holding junior rights.

One problem that arose was how to determine who was the first to put water to a beneficial use and, thus, entitled to the prior right. Was it the first person to complete construction of a facility to divert, transport and use the water, or was it the first to announce his intention to do so and begin construction? This led to what is called the "doctrine of relation back." According to this, "between two persons digging ditches at the same time, and prosecuting work thereon with reasonable diligence to completion, the one who first began work had the prior right, even though the other had completed his first" (Huffman, 1953:43). This eliminated the incentive for hasty and shoddy construction which would have been inherent if the prior right had been based on completion of the structure.

In many states following the prior appropriation doctrine, the defining of the water rights is left to the courts and usually occurs when there is a conflict between two or more parties over the water. "When rights are adjudicated by the courts, certificates are issued to the holders of rights stating the volumes of water to which they are entitled, the dates of their rights, and the number of rights in the order of their priority" (Huffman, 1953:46). The certificate does not, however, establish whether there is enough water in the stream to supply all of the rights.

6.2.1 Security of the Water Right

From an economic standpoint, one of the most important features of a system of water rights is the security of the right. In general, ceteris paribus, the more secure that water rights are, the more investment there will be in water resources development. As defined above, there are two types of uncertainty, "physical uncertainty" and "tenure uncertainty." Appropriative rights are more secure against tenure uncertainty than are riparian rights. While appropriative rights are clearly defined in terms of priority, quantity, period of use, and points of diversion, "riparian rights are co-equal and quantitative definition depends on adjudication, which is in terms of shares and subject to the restriction that there shall be reapportionment if the conditions upon which the original apportionment was made change sufficiently to justify it" (Ciriacy-Wantrup, 1964:256).

Several factors can reduce the security of tenure, however. The first is prescription whereby the state retains the right to take water for a public purpose. The holding of water rights for future use, termed "reservations" or "restrictions" is another. While water may presently be available for appropriation by anyone, the presence of a reservation may provide a disincentive for others to invest in developing a use for it. How these factors affect the security of the investment depends on whether or not compensation is paid and, if so, how much. If compensation equal to the value of the cost of development of the resource is paid when prescription or reservation is exercised, then these are not disincentive factors.

As for security against physical uncertainty, a senior right under prior appropriations has more security than a junior right. The differentiation of preference classes affects the physical uncertainty. Customary preference classes are "natural" and "artificial" under a system of riparian rights and "domestic," "municipal," "agricultural," "industrial," and "recreational" under appropriations. The positions of agricultural and industrial uses are reversed in some states, and as industrial development takes place in agricultural states, there is conflict over which should have preference. Under a system of prior appropriations, these preferences operate before rights are allotted, and under both systems, the preferences operate in times of emergency. Of course, the time of shortage is when one, particularly an irrigator, can ill afford to lose access to water, so this can be a serious source of insecurity.

Generally, some form of the doctrine of prior appropriations provides investors more security that they will be able to appropriate the income stream created by their investments to develop an irrigation system. It is for this reason that it is seen most often in areas where water is scarce and, consequently, of high value.

6.2.2 Physical Irrigation Works

People obtain property in three broad ways: originally, derivatively, and by succession. Original ownership can come about through creation (i.e., by making something) or through occupation (i.e., by staking a claim to ownerless property). Derivation involves acquiring by purchase or gift, and succession is acquisition by inheritance (Hollowell, 1982). In the first instance in irrigation development, property is obtained originally through both creation and occupation. The construction of physical irrigation works, i.e., the diversion and canals, establishes a claim to the water. Later on, property rights in the water may be sold and bequeathed--often along with the land to which the water is applied.

It is the act of investing in the creation of the irrigation works that legitimates or justifies the claim to ownership of property rights in the water. This is stated explicitly in the statutes of states with a formal doctrine of prior appropriation and is implicit in the traditional, customary water rights in the farmer-managed irrigation systems in many parts of the world. The original investment in property creation and the current structure of property relations may take one of several forms. Coward (1983) describes five different types of ownership observed among systems in different parts of Asia. These he refers to as (1) the communal form, (2) the investors' group form, (3) the atar system, (4) the local government model, and (5) the elite-owned system.

In the communal form, of which the subaks of Bali are cited as an example, the irrigation works were built by a group of irrigators and are jointly owned by all of the current irrigators who are successors to the original owners. The maintenance and improvement of the hydraulic works are the responsibility of the joint owners, and they have the rights to all of the water in the irrigation system. Land is owned and farmed individually by the farmers.

The investors' group form differs from the communal form of ownership in that the irrigation works are owned by a subset of those farmers who own land that is irrigated by water from the system. This subset of farmers, who have property rights in water, are those who made the original investment to construct the system. They are responsible for the operation and maintenance of the system. The nonowner irrigators may be charged water fees and be required to do some work on the system. Lando (1979) describes a system with this form of ownership in North Sumatra, Indonesia.

The atar model found in the Ilocos Norte region of the Philippines is an example where the irrigation works were developed and are owned by a group of persons who possess no land which can be irrigated (Siy, 1982). In exchange for building, operating, and maintaining the system to irrigate land owned by others, the members of the zanjera (irrigation organization) obtain rights of usufruct to some of the land which can be irrigated. As long as the zanjeras provide satisfactory irrigation services, the members are entitled to use of the land.

Local governments commonly own and operate various items of public works. In some villages on Java, the local government owns and operates the irrigation facilities. These village-owned irrigation works may be a "village irrigation system" owned wholly by the village or jointly with other villages, or they may be terminal-level facilities of a large system whose main structures are owned and maintained by an irrigation agency of the national government. The local government develops and maintains that part of a system which it owns. This it does "through its power to assess special payments from cultivators, its ability to allocate resources from the annual subsidy funds provided by the national government, and its ability to solicit special funds from the various units of government above it" (Coward, 1983:9). Often there is a specified village government staff member responsible for irrigation matters.

Another form of ownership under which systems were developed is referred to by Coward as the elite-owned model. This is no longer a prevalent ownership pattern, but in the past, systems in Thailand, Nepal, Sri Lanka, and other countries were constructed and operated under the authority of elites. These persons often had sizeable land grants from the ruling power and the right to extract corvee labor from the peasants who farmed the land as tenants. Where feasible, this labor was often used to construct and maintain irrigation works. It was the elite figure who was the owner of the system and who organized, usually through his agents, the construction, operation and maintenance of the irrigation system. In most cases these systems are now either owned by the farmers who cultivate the land irrigated by the system or have been incorporated into larger government-managed systems.

In each of these cases, the developers of the irrigation works property were able to establish property rights in the water. As under the doctrine of prior appropriation, by making an investment to put the water to a beneficial use, i.e., irrigation, the original investors were able to acquire the rights to the water. They could use the water themselves or, through some form of transaction, alienate it to others. The prevailing customary structure of property rights granted to them the right to use the water after the system was constructed (or perhaps even before construction in some cases) and imposed upon others the duty of not interfering in the supply of water to the owners of the rights. In many cases, the act of building the structures to divert and convey water was sufficient "justification" for ownership of the water rights. In some situations there may have been a formal granting of a property right in the water by higher authorities. The security of the property right was sufficient to bring forth significant initial as well as continuing investments of resources, primarily labor, to develop and maintain the irrigation systems.

While the original property creation may have taken one of several forms, the current owners, if they are not the original developers, participate in that investment by either having bought or inherited the property. As Coward notes, "Nonowners who wish to become owners may be asked to make large payments which represent the owning group's assessment of a fair portion of the original investment which newcomers should duplicate" (1983a:11-12). The same was observed in Chherlung in Nepal as will be described in the following chapter.

Having established the right to the water in a source through the construction of the hydraulic works, an irrigation organization will often have to limit the expansion of the system. With rapidly increasing demand for agricultural production in countries like Nepal due to high population growth rates, there is pressure to intensify production, and all farmers desire irrigation for their fields. In areas that are water constrained, i.e., the supply is insufficient to irrigate effectively the entire command area, organizations must have a means of restricting access to the system. Maass and Anderson found in their study of irrigation organizations in Spain and the western United States that "the strength and coherence of local irrigation organizations in developed regions appears to be correlated with an irrigation community's success in limiting or stabilizing growth, thereby gaining security for its members" (1978:368). If within the system, water is allocated on the basis of strict prior appropriation, then no other procedure is needed for accomplishing this. However, if the principle is that all farmers receive water in proportion to the land they irrigate, then some other limiting procedure is needed or else farmers would continue to join the organization and receive water in proportion to their land until the system would break down because of insufficient water. Maass and Anderson (1978) report several procedures for restricting the expansion of the system including the following: defining the limits of the irrigation community and providing that no water may be delivered outside of these; specifying the canal system and providing that it may not be extended; registering the land that may be irrigated or the farm turnouts from which water can be drawn and providing that no others be used; providing that supplemental water sources be delivered by the same procedures or through the same distribution system or to the same lands as the principal source; or some combination or variation of these.

Having looked generally at the creation of irrigation property and the issue of the security of the investment to create property, the following section examines these irrigation property issues in Nepal.

6.3 Property Rights in Water in Nepal

Water is an extremely important resource in Nepal, and with rice being the preferred food staple of most of the population, irrigation is a critical input in agricultural production.[4] Property rights in water have been clearly defined, by custom if not by statute. At the national level, the present law of Nepal says little about water for irrigation. The Irrigation, Electricity, and Related Water Resources Act of 1967 has the following clauses relevant to water rights for irrigation:

3. Use of Water Resources

(1) No person shall be permitted to utilize a water resource without obtaining license under this Act. But no license need by obtained for utilizing any water resource for any of the purposes mentioned below:

(a) For meeting daily personal needs,

(b) For operating windmills for cottage industry purposes,

(c) For operating water mills or irrigation channels,

(d) For irrigating lands through underground water by means of tube-wells,

(e) For drawing water for irrigation purposes from gullies, aqueducts or streams, ponds, wells, lakes, canals or dams through the labor and resources of the local people themselves either individually or collectively, in such a manner that no adverse effect is created on any hydroelectric or irrigation project of His Majesty's Government constructed before or after commencement of this Act, or those proposed to be constructed in the future.

6. Acquisition and Requisition by His Majesty's Government

(1) His Majesty's Government may acquire any electric and irrigation installation and related equipment against compensation, if it so becomes necessary for the purpose of making large-scale and comprehensive arrangements regarding electricity and irrigation.

(3) Canals, dams, electric installations, any other construction project and related lands and equipment acquired under this section may be operated by His Majesty's Government itself or be handed over to any other person for operation with or without selling the same to him.

---

[4]Although some unirrigated upland rice is grown in Nepal, by far the majority is produced under irrigated conditions.

This act recognizes the right of individuals and groups to construct irrigation systems. Water may be diverted from rivers, streams, lakes, and ponds and extracted from underground sources provided this does not adversely affect an irrigation or hydroelectric project constructed or being planned by the government. No license is required for developing an irrigation system. The act reserves for the government the right of taking over an irrigation system if it interferes with the development of a larger irrigation or hydroelectric facility. If this is done, the act provides that compensation is to be paid but says nothing about the rate of compensation.

Most of the farmer-managed irrigation systems in Nepal were initiated long before this legislation of 1967 was enacted, and the property rights in water were subject to other laws and customs. The Law on Reclamation of Wasteland[5] (Regmi, 1978:244) indicates some of the principles of property rights in water followed in earlier times:

1. Water shall not be available for others until the requirements of the person who constructed the irrigation channel at his own expense or with his own physical labor are first met. In places where water has been shared in the past, no one shall be allowed to withhold the usual share of the water, thus making a field uncultivable. After the field at the source of the water is irrigated, the next field shall use the water. If the owner of the field at the source is confronted with any difficulty, the owner of the next field shall use the water for cultivation. A new irrigation channel may be constructed at a point higher than the existing one only if the amount of water available to the field irrigated by the old channel is not reduced.

2. If an irrigation channel tumbles down or the field is damaged by streams or washouts, the landowners (Mohi) themselves shall repair it as far as possible, or do so by jointly providing laborers. They shall not share in the water supply unless they themselves make repairs or provide laborers. If the strength or resources of the landowners prove inadequate, the Talukdar shall ascertain the resources required to repair it and report to the Government office. He shall have an order issued and then repair the channel. When the channel is repaired with means

---

[5]This law is in Mahal 8 of the Muluki Ain (Legal Code of Nepal) and is included as Appendix J in Regmi (1978).

provided by the Government, the existing landowners shall not be evicted. If the irrigation channel is not repaired by either the Government or the tenant for three years, and the local Talukdar repairs the land or the channel at his own cost after reporting the matter to the central Government office, he may take eviction measures. The existing landowner shall not be allowed to complain that he has been evicted from the land.

3. Dams or irrigation channels may be constructed on any land, cultivated or uncultivated,. . . to bring into cultivation any land . . . .No obstruction shall be caused. The owner of the land shall be compensated with the value of the cultivated land taken up by the dam or irrigation channel, or given other land in exchange. But if the land that is thus taken up is uncultivated land not liable to taxation, no compensation shall be paid. When land owners incur expenditure on irrigation works to bring waste land into cultivation, if the tax on the newly cultivated waste land is double that being paid on the cultivated land taken up by the dams or irrigation channels, the tax for the land taken up by the dams or irrigation channels shall be remitted.

These paragraphs clearly enunciate principles of property rights in water for irrigation. Construction of the irrigation works is what gives one entitlement to the water. This water right is defined by the general doctrine of prior appropriation. Accordingly, it is not permissible to take water out of a source above an intake for an existing irrigation system if by doing so the amount of water available to the older system will be reduced. First-in-time, first-in-rights is the principle. Security of property rights is also established by the statement that in places where water has been shared in the past the usual share of it cannot be withheld.

In the second paragraph, the need to participate in the continuing maintenance of the system in order to justify one's water right is emphasized. Landowners who do not assist in the repair of a system may be evicted from their land. The third paragraph implies that one does not have to have riparian land to acquire water rights for irrigation. The water can be taken wherever one wants to use it, and persons with riparian or other land between the source and the land which is to be irrigated cannot obstruct the construction of a canal across their land. If the land on which a dam or canal is constructed is land that is cultivated, the owners are entitled to compensation equal to the value of the land lost from cultivation due to the construction. No compensation is due if the land has not been cultivated.

6.4 Field Observations

6.4.1 Argali

The observations made while studying a number of farmer-managed systems confirmed that property rights in water are well defined and that water rights in a stream are allocated under a principle of prior appropriation. In Argali, both the Raj Kulo and Kanchi Kulo canals have hydraulic command areas nearly twice as large as the area they irrigate during the monsoon rice season. Member farmers recognize that more area could be irrigated by the systems if more technically efficient distribution practices were adopted. This was evident from conversations with a group of the Raj Kulo system farmers. They were asked which particular area, if any, in addition to what is irrigated at present they would irrigate if they individually owned the entire command area of the Raj Kulo. The purpose of the question was to investigate their knowledge of the local soils and which they thought would be most suitable for irrigated rice cultivation, i.e., which would have a higher water-holding capacity. The somewhat surprising and enlightening reply was that they would irrigate the entire command area. To do so they would change to rotational distribution. It was their perception that the entire area could be effectively irrigated if more intensive management for distribution were instituted. However, because the farmers who own the approximately 47 hectares that are now being irrigated have the right to use the water for irrigation (a right that is tied to the land) and those owning land in the rest of the command area do not, only the 47 hectares are irrigated.[6]

That the priority of the right to the water of the first organization to construct an irrigation system is recognized is attested to by the commonly heard statement that building a new intake upstream within a hundred gaai[7] of an existing one is prohibited. The first article of the constitution of Argali's Raj Kulo organization expressly states that no one is permitted to construct a diversion in the stream within 100 gaai upstream of the intake of the Raj Kulo canal. In addition to hearing this principle stated many times, there is also physical evidence that it has been followed.

The position of diversion structures and the layout of the main canals in several locations including Argali and Chherlung provide visual evidence of the doctrine of prior appropriation. At one time, people in these places who had land above (or upstream from) fields that were already being irrigated wanted to construct a canal to irrigate their land. Because of the existence of a previously-constructed canal and the doctrine of prior appropriation, this later canal had to locate its diversion downstream from the existing intakes, even though the land to be irrigated was above that irrigated by the older canal. This later canal had to be built with a lower gradient, and had to cross the existing canal. This is true of the Saili and Maili canals in Argali and the Tallo Kulo and Thulo Kulo canals of Chherlung.

---

[6]As was explained in Chapter 3, water allocation in the Raj Kulo system is in proportion to the amount that a field occupies relative to the total 47 hectares that are irrigated. The water right is defined for only that 47 hectares during the monsoon season.

[7]A gaai is a unit of length equal to one yard or approximately 0.9 meters.

6.4.2 Kotagaon

This principle of prior appropriation is upheld in the courts, as confirmed during a rapid appraisal of the Parbati Kulo system in Kotagaon of Tanahu District. The farmers of Kotagaon operate the Parbati Kulo irrigation system on one side of a stream. Farmers of Kalikatar have a diversion structure downstream of the Parbati Kulo system's intake and irrigate fields in their village on the other side of the stream. Recently, the farmers of Kotagaon began to construct a second main canal a little below the existing one. The diversion for this second canal was located only a few meters downstream of their original intake and was intended to capture water that escaped the first diversion. The farmers from the Kalikatar irrigation system objected to this because it would decrease the supply to their canal. They took their complaint to court in the district center, and the court decided in their favor, recognizing the right of the Kalikatar farmers to all of the water in the stream below the Parbati Kulo system's original diversion. Kotagaon farmers had to abandon their scheme for increasing the supply in their system at the expense of the farmers of Kalikatar. The system of property rights in water granted the Kalikatar farmers the privilege of using all the water in the stream below the diversion of the Parbati Kulo system and imposed on the farmers of Kotagaon the duty of not interfering with the water that was in the stream below their intake. The abandoned canal intended to serve the Kotagaon command area remains as visible evidence of the recognition by the district court of the doctrine of prior appropriation in the assignment of property rights in water.

6.4.3 Chherlung: Tallo Kulo

The case of the Tallo Kulo irrigation organization in Chherlung and the history of its claims, conflicts, and negotiations over water rights is revealing of some of the customary principles of water as property in Nepal. The Tallo Kulo, the second system built to irrigate the river terraces in Chherlung, was originally constructed because some people in Chherlung held property rights to water and others did not. The story began in 1933 when the Thulo Kulo, the first canal to bring water to Chherlung from the Brangdhi Khola stream, was completed. The construction of the Thulo Kulo system had been organized and financed by a group of 27 households. When the project was completed, the water was divided into 50 shares with a share representing one-fiftieth of the Rs. 5,000 cost of constructing the system as well as one-fiftieth of the total discharge of the canal. Shares were divided among the original 27 households in proportion to their investment in the construction, and they were able to sell shares to other residents as well.

At that time, households in the upper area of Chherlung wanted to purchase half of the water to irrigate land that was located above the fields which were served by the Thulo Kulo system. The original members of the Thulo Kulo organization were not prepared to sell nearly this much water. Because they could not acquire the rights to as much water as they wanted from the Thulo Kulo, Hasta Bir Thapa and Pratap Singh Saru initiated the construction of the Tallo Kulo irrigation system. Two canals, the Thulo Kulo and the Toplek-Pokhariya[8] canals, had already been constructed with intakes on the Brangdhi Khola stream. In accordance with the doctrine of prior appropriation, the intake of the Tallo Kulo system had to be located

[8]The Toplek-Pokhariya canal, which irrigated fields in Toplek and Pokhariya located between Chherlung and the Barangdi Khola stream, was constructed before the Thulo Kulo canal.

downstream of the diversion structures of these two irrigation systems. Since the area irrigated by the Tallo Kulo system is above that irrigated by the Thulo Kulo system, the Tallo Kulo canal had to be built with less of a gradient than the Thulo Kulo canal, and the two canals cross just as they arrive in Chherlung.

Construction of the Tallo Kulo canal was completed in 1938, and water rights were allocated by selling shares in the system. The water in the system was divided into 55 shares valued at Rs. 100 each, equaling the total cost of the contract of Rs. 5,500 for construction of the canal. Water rights continue to be allocated through sale of shares. Maintenance and improvement of this canal, which is approximately six kilometers long and cut into sheer cliffs at some places and dug along unstable, landslide-prone slopes at others, has required the mobilization over the years of large amounts of resources from all those owning shares in the system.

In 1976, the flow in the Brangdhi Khola stream at the intake of the Tallo Kulo canal dried up. Apparently, a spring that previously had surfaced in the stream bed between the intake of the diversion for the Toplek-Pokhariya canal and the intake of the Tallo Kulo canal had shifted and come to the surface at some other location downstream. The Tallo Kulo farmers were not permitted, by the doctrine of prior appropriation, to acquire water by diverting it from the stream above the two prior-existing intakes nor was it feasible to construct a new canal below theirs. They faced a severe economic crisis without water to irrigate their fields. Their only alternative was to somehow acquire rights to use of water captured by one of the other diversions. After some intense bargaining, including a lavish feast put on by the Tallo Kulo farmers, an agreement was reached with the farmers from Toplek and Pokhariya to share their intake and canal. The terms of the transaction recognized the prior claim that Toplek and Pokhariya had to the water because of having made the earlier investment to develop an irrigation system. Farmers of the Tallo Kulo system agreed that they would (1) broaden the existing Toplek-Pokhariya canal so that it could carry more water, (2) do all of the routine maintenance of the canal and diversion structure exempting the Toplek-Pokhariya farmers from this recurring expense, and (3) supply adequate water to Toplek and Pokhariya. In times of emergency, farmers from Toplek and Pokhariya would be required to contribute to the repair work after being informed in writing.

The Toplek-Pokhariya organization interprets the agreement as having granted the Tallo Kulo organization access to the intake and canal but not giving them water. The water to which Chherlung was given rights was to be the additional that could be delivered as a result of their investment in widening the canal. A sum of Rs. 7,200 was reportedly invested to make the improvements in the canal. Initially, Toplek and Pokhariya received all of the water during the day, and the Chherlung farmers could only irrigate at night. Since the supply has been increased, saachos have been installed to apportion to Toplek and Pokhariya their share, i.e., half of the water, and these two areas and Chherlung receive water continuously.

The Tallo Kulo farmers have recently been involved in negotiations with another village over water rights. This is the village of Artunga which lies approximately two kilometers west of Chherlung (i.e., two kilometers farther from the Brangdhi Khola stream) in Argali Panchayat.

The situation began when the Tallo Kulo farmers, through the village panchayat, requested assistance from the district panchayat to improve their irrigation system. (Despite the agreement with Toplek-Pokhariya and the improvements to the canal, they had been experiencing water shortage.)

Since the neighboring village of Artunga had no irrigation system, the Palpa District Panchayat responded by sanctioning a project that was designed not only to help the Chherlung Tallo Kulo farmers, but Artunga as well. A grant of Rs. 100,000 was provided to make improvements to the Tallo Kulo canal with the intention of the district panchayat that it be extended to provide irrigation for farmers in Artunga as well. It is this project (authorized in 1978) which has resulted in ongoing conflict between Chherlung and Artunga over water rights.

In March 1979, a meeting was held to decide on arrangements for carrying out the project. Thirty-six people were at the meeting including members of the Tallo Kulo organization from Chherlung, persons from Artunga who were to benefit from the project, officials from the two village panchayats, a member of the district panchayat, the local development officer, and the district engineer. No one from Toplek or Pokhariya was present. Several decisions were recorded in the minutes of the meeting. A nine-member construction committee was selected to oversee the work and make reports to the district panchayat. It was composed of men from Chherlung and Artunga as well as the two village panchayat chairmen and a member of the district panchayat. Chherlung and Artunga were to share equally the work of improving the existing canal, while Artunga farmers would be responsible for building the extension to their command area.

The decision made at this meeting concerning allocation of the water after completion of the project is hard to understand. The minutes report that it was decided that after the project was completed, land in Toplek, Pokhariya, Chherlung, and Artunga could be irrigated. Further, it says that the district panchayat shall be requested to see that the allocation of water is done in a "proper and just manner, taking into consideration the land area of the respective places." Since the irrigable area of the Tallo Kulo farmers in Chherlung and that of Artunga were approximately the same,[9] an allocation according to land area would give the two nearly equal shares of water, with Artunga actually receiving slightly more. Dividing the supply in this manner would result in the Chherlung farmers losing a significant portion of their water. This goes against the doctrine of prior appropriation which was evident in the original construction of the Tallo Kulo canal and the agreement worked out between Chherlung and Toplek-Pokhariya. It is now apparent that the Toplek-Pokhariya and Chherlung Tallo Kulo farmers did not actually agree with the decision on water allocation as recorded in the minutes.[10] Apparently it was nominally accepted by the Chherlung farmers so that the project could proceed.

Construction work was completed in May 1981, shortly before the onset of the monsoon, and conflict over the water began immediately. One source of contention was the question of how much the improvements to the canal had increased the supply. The Chherlung farmers said that most of the lining of the canal that was done to increase the delivery efficiency washed out in the monsoon the first year, and the amount of water available did not increased measureably. The _mukhiya_s (leaders) of the Toplek and Pokhariya systems estimated at one meeting that the supply had been increased by approximately 35 percent. Artunga farmers felt there was a greater increase. The fact that there had been no measurement of the flow before and after the construction left it impossible to establish whether and how much the supply had been increased.

---

[9]Artunga listed a total of 510 ropanis or approximately 26 hectares, and Chherlung, 471.4 ropanis or 24 hectares.

[10]It should be noted that the most important and influential member of the Tallo Kulo organization, the _mukhiya_ (leader) was not present at this meeting, and there was no representation from Toplek and Pokhariya.

The main source of conflict was over the rights to the water. A letter was sent in April 1982 to the District Local Development Officer by the chairman of the construction committee reporting that the construction had been completed and asking the district panchayat to arrange the water allocation. Enclosed was a copy of the minutes of the March 1979 meeting, mentioned above, at which the water allocation had been discussed and a listing by farmer of the irrigable area under the Tallo Kulo canal in Chherlung and Artunga.

Between June 1982 and December 1983, a number of meetings were held to discuss and negotiate the matter. Those attending the meetings varied, but the Chherlung farmers were at all of them, Artunga farmers at most, and village and district officials at some. Toplek and Pokhariya farmers were not in attendance at many of the meetings. The primary points of debate and discussion included:

1. Chherlung said that the interpretation of the phrase stating that water allocation should be done in a "proper and just manner, taking into consideration the land areas of the respective places" was that after they had adequately irrigated their area, any remaining water should be sent to Artunga. Artunga held that it meant that the supply should be divided proportionally according to the respective areas, or at a minimum that they should get a fixed share of at least one-fourth if not one-third of the supply.

2. Chherlung insisted that if they had to give up water to Artunga, then Toplek and Pokhariya also had to give up a proportional amount.

3. Toplek and Pokhariya maintained that they had not given up any of their rights to water to Chherlung. They had only allowed Chherlung to use their intake and canal. Thus the transaction should be only between Chherlung and Artunga.

4. Chherlung was willing to give up some water if Artunga bought it at the going price like farmers in Chherlung had. By doing so, Artunga would be participating in the original and continuing investment in the system. To the Chherlung farmers it was unjust for the Artunga farmers to receive half of the water after putting in the little amount of effort they had in one year to repair the canal.

5. Artunga refused to buy water on the grounds that the project to improve the canal to deliver more water so that they could get a share of it had been funded by the government as a development activity.

6. District officials, while determined that Artunga should receive some water, preferred that the contending parties work out an arrangement themselves rather than have the district impose a settlement.

7. The Chherlung farmers were extremely keen to settle the matter locally without formal involvement of the district officials. The organization did not want to lose its autonomy.

During this period from the completion of the canal in May 1981 through the time of the meetings, Artunga received water for irrigating wheat in the winter--a significant benefit. However, no water went to Artunga during the monsoon rice seasons of 1981, 1982, or 1983. (As noted earlier, water rights in nearly all of the systems observed were the most precisely and restrictively defined for the monsoon rice season.)

Finally in January 1984, an agreement was reached which involved only the farmers from Chherlung and Artunga. Chherlung agreed to divide its supply into 59 shares instead of the 55 as it had been doing. Four of these 59 shares were to be allowed to pass on to Artunga during the monsoon rice season. This amounted to less than seven percent of the supply instead of the 25 to 50 percent for which the Artunga farmers had been asking. In exchange for these four shares of water, Artunga was to provide 16 laborers whenever maintenance work needed to be done on the canal. (From Chherlung labor mobilization is at the rate of one laborer per share.) However, when cash was to be raised for repairs and improvements, it would be at the same rate per share in both locations. Artunga would continue to receive water in the winter as it had been since completion of the project.

The final settlement recognizes the prior rights of Toplek, Pokhariya, and Chherlung to the water as a result of earlier investments and protects the security of those investments. Toplek and Pokhariya, with the most senior right, were not part of the final agreement. They continue to receive half of the supply and are exempted from ordinary maintenance work in accordance with their original agreement with the Chherlung farmers. In accepting such a small amount of water and agreeing to contribute four times as much labor per share as Chherlung, Artunga recognizes Chherlung's right of prior appropriation because of Chherlung farmers' investment in the original construction and years of sweat and toil to maintain the canal.[11] In being readily willing to allow Artunga water to irrigate in the winter, Chherlung is recognizing the principle of beneficial use. There is more water available than they need for their wheat crop so they are prepared to allow Artunga the use of the canal to acquire this water. Before the 1984 agreement (during which time Artunga received water to irrigate winter wheat but not monsoon rice), Chherlung did not require Artunga to participate in the maintenance of the canal. Their 50-percent participation in the improvements under the government-funded project was considered sufficient to earn the right to the residual water in the winter. Also Chherlung did not want to give Artunga any additional grounds for claiming water rights, which regular participation in the system maintenance would have done.

Chherlung's granting of four shares of water to Artunga for the monsoon season was only under pressure from the village panchayat and

---

[11]The farmers from Artunga also realize that they must work in a cooperative relationship with the Chherlung farmers if they are to receive a reliable supply. This was given as a reason why they did not push harder for a settlement imposed by the district officials that would have given them a larger share of the water.

district officials. Allowing Artunga water without their buying shares in the system as all the Chherlung farmers had done violated their institution of property rights. The Rs. 100,000 from the government and the estimated Rs. 62,000 of labor that the Artunga farmers had contributed to improving the original canal did not represent much investment compared to the original construction of the 6-kilometer-long canal and the 2,000 or more man-days of annual maintenance labor for 45 years. Having accepted the project and been party to a document, ambiguous though it may have been, concerning the post-project allocation of water, Chherlung was not in a strong position to deny Artunga water completely for its monsoon rice crop. However, the terms of the final agreement certainly recognized Chherlung's prior rights.

The discussion thus far has been about the collective right of a group of farmers, who are members of an irrigation organization, to the water in the source at the intake of the system's canal and the establishment and security of this right through the doctrine of prior appropriation. In the hills of Nepal where landholdings are small, there is a great deal of interdependence among irrigators for acquisition and distribution of water as well as maintenance of the physical works. Operation and maintenance of the system, not to mention the original investment, is beyond the means of the individual farmer owning less than a hectare of land. For this reason, the right to water in the source and the ownership of the hydraulic works are vested in a group of farmers rather than an individual.

We now want to examine the nature of the property relations among the members of the irrigation organization. Within an irrigation system the water supply is allocated among individual farmers through a system of property rights. The following section will look at the security of the water rights of the individual member farmers.

6.4.4 Individual Farmers' Water Rights

In most of the systems, individual farmers know the amount of water to which they are entitled, usually as a proportion or share of the total discharge in the system. Since most of the farmer-owned and -managed systems are generations old, the present owners have acquired their property rights either by inheritance or purchase. In most cases, the water rights are appurtenant to the land,[12] and farmers acquire water rights through land transactions. As has been mentioned and shall be described in fuller detail in the following chapter, there are irrigation systems in Nepal in which ownership of water rights and transactions of these property rights are completely independent of land ownership.

In Argali, Chherlung, and Majuwa, farmers could readily report the amount of water to which they had a right. The water rights in Argali and Majuwa are denominated in muri, a traditional unit of area.[13] A farmer is entitled to a proportion of the total supply in the system equal to the number of muri he has, divided by the total number of muri in the system. In Chherlung, water rights are designated in rupees, and Rs. 100 represents one share. This convention remains from when the original Rs. 5,000 cost of constructing the canal was divided into 50 shares valued at Rs. 100 each. Although the price of a share now far exceeds Rs. 100, the original denomination of the shares has been maintained from the beginning.

The security of the individual farmer's water rights within the system is determined by the (1) type and precision of the method of distribution and (2) sanctions concerning water stealing. Proportioning weirs (saachos) and

---

[12]That the water rights are "appurtenant" to the land means that they are tied to the land and cannot be exchanged separate from land transactions.

[13]According to Regmi (1978) the area of a maato muri was fixed at 1,369 square feet in 1907. At this rate one hectare equals 78.6 maato muri.

rotational distribution are the two main methods used to ensure that each farmer receives water in accordance to his allocation. Measurement of the flows in various secondary canals in both the Kanchi Kulo system of Argali and the Thulo Kulo system of Chherlung, comparing the proportion of the actual flow in each secondary with the proportion of water rights to be served by the given secondary, revealed that the distribution matched the allocation quite well, as shown in Table 6.1.

Table 6.1 Water Allocation vs. Water Distribution in Selected Secondaries

System	Secondary	Water Allocation (%)	Water Distribution (%)[a]
Thulo Kulo, Chherlung	B (head)	9.5	10.2
	E (middle)	11.4	10.5
	G (tail)	21.8	20.6
Kanchi Kulo, Argali	A (head)	5.8	b
	E (tail)	16.6	16.9

[a]Measured discharge during the monsoon rice season.
[b]This secondary served only two fields and was not used all of the time. One of the fields received water continuously from leakage from the main canal and the other from another secondary.

The figure in the water allocation column represents the percentage of supply that has been allocated to the area served by each secondary. For example in Chherlung, 9.5 percent of the shares in the system have been assigned to the fields that are served by secondary B. Thus 9.5 percent of the supply should be distributed to secondary B. The actual measured discharge during the monsoon rice season shown in the water distribution column was 10.2 percent of the total flow in the system, which is remarkably close to the allocation for that secondary. As seen from the table, the distribution in the other two secondaries for which it was measured was equally accurate. (Measurement was done only on these three of the seven secondaries, giving proportions in head, middle, and tail sections. If all seven had been measured, the discharge should have totaled 100 percent of the total flow.)

In the Kanchi Kulo the flow in two of the five secondaries was measured (secondaries A and E in the table). The table shows that the distribution to secondary E very nearly matched the allocation to which it was entitled. As explained in the note in Table 6.1, secondary A was not in operation for a good part of the season, so calculation of the proportion of the supply received by the fields which it was to serve was not possible.

The accurate proportioning of the water by means of saachos and the precise calculation and implementation of the rotation schedule enable the physical distribution of the water to match closely the water allocation (distribution of water rights). In other words, the security of the individual's investment is high.

A record of each farmer's allocation of water rights is generally kept by the secretary of the organization. As noted in Chapter 5, a precise record of each farmer's water allocation is more likely to be kept if the system requires a large amount of resources to maintain the structures for acquiring water than if it does not. The ownership of a share of the water has concomitant duties. Farmers owning rights to shares of water justify their continuing ownership by contributing labor and cash for the ongoing maintenance of the system. In Argali, Chherlung, and Majuwa, the mobilization of these resources for maintaining the system is based on the individual farmer's water allocation.

In Thambesi the amount of resources required for maintenance of the system is much less than in the other sites, and there is no systematic procedure for mobilizing resources. As a result, there is no record of each farmer's water allocation, i.e., the amount of his water right. Farmers here could not respond in a meaningful way to a question asking the amount of their water allocation, while the farmers in the other three locations could readily report the number of muri or the number of shares to which they were entitled. In Thambesi, there was also a much greater variation in the adequacy of the water supply delivered to different parts of the system than in the other systems. The fields in the tail of the Thambesi system had much higher stress-day counts than those in the head areas and suffered yield-reducing stress. The security of the Thambesi tail-end farmer's investment in the system is low, but the amount of his investment is also low compared to the other systems. In the other systems, there was no systematic difference in the adequacy of water supply. Differences in stress-day count were attributable to individual farmers' practices rather than to the system's serving some parts of the area better than others.

6.5 Common Property and the Assurance Problem in Irrigation

As was stated before, a farmer-managed irrigation system exhibits the characteristics of common property, and the irrigation organization and the rules and procedures by which it operates can be seen as endogenous responses to the problems of the management of common property. The term "common property" "refers to a distribution of property rights in resources in which a number of owners are co-equal in their right to use the resource" (Ciriacy-Wantrup and Bishop, 1975:714). It does not mean that the co-equal owners are necessarily equal with respect to the quantity of the resources each uses over a period of time.

The problems of common property are often confused with those of open access, and it is important to distinguish between the two. Problems of open access arise from the inability to restrict entry while common property problems pertain to property rights of a group of a given size (Runge, 1981). A farmer-managed irrigation system usually consists of a well-defined group of farmers, and persons from outside the group can generally be excluded from benefiting from the system, i.e., it has the characteristics of common property.

A key problem in the management of common property is one that has been referred to as the "assurance problem" (Sen, 1967). Runge (1981) analyzes the assurance problem within the context of common grazing land utilized in the raising of cattle. To maintain the viability of the grazing land, it is necessary to restrict the number of cattle feeding on it. The problem in this case as it was articulated by Hardin (1977) is that the private benefit of grazing an extra head of cattle on the common range exceeds the private cost, because part of the cost is borne by the entire group engaged in grazing. It is thus rational on the part of each individual herder to keep adding cattle to his herd even though in the aggregate this will result in destruction of the pasture land and, thus, loss of the source of income. With the assumption of separable cost functions for each cattle owner and, most importantly, assuming that individuals act independently, the inevitable result will be overgrazing and destruction of the commons, i.e., the "tragedy of the commons" (Hardin, 1977).

Runge has argued that the assumption of separable cost functions is not valid in the common property problem. The individual profit-maximizing solution of equating marginal cost to marginal benefit is not a dominant and determinant outcome because of the fact that joint use of the common resource is not a separable decision. Choices about resource use are conditioned by expectations of the likely behavior of other members of the group.

> In the nonseparable case, the externality enters the cost function of each individual in a multiplicative rather than additive way...In contrast to the separable case, marginal cost is affected here not only by the variable under control of the individual, but also by the other's choice variable. Because each person's marginal conditions for profit maximization are affected by the grazing decisions of others, there is no well-defined decision rule for each individual. . .One cattle owner's decision to graze cattle generally will depend on his expectation of the behavior of others (Runge, 1981:599-600).[14]

Institutions that give each individual cattle owner the "assurance" or expectation that the others will stint, i.e., will restrict the number of cattle they graze, are needed to convince each individual that his stinting will contribute to the long-term viability of the grazing land. These institutions, such as a customary rule that each grazer is expected to stint at an arbitrary level (q*), "formalize for each grazer j the expected actions of others at level q*. Each expects the others to graze at level q*, and, with this assurance, agrees to do the same" (Runge, 1981:602). Institutions which provide security of expectation, or assurance, are endogenous responses to the uncertainty of social and economic interaction.

The irrigation works represent common property that must be maintained by the group of farmers if it is to retain any utility. The mobilization of resources, in particular labor, from the members for system maintenance is one instance of the assurance problem, and institutions that effectively deal with this problem must evolve if the system is to be viable.

---

[14]A function with more than one argument is said to be separable if when the partial derivative is taken with respect to one of the variables only that variable is included in the expression of the partial derivative. The values of the partial derivative will, thus, be independent of the values of the other variables in the function.

The problem of mobilizing resources to maintain the common property of the irrigation works might be thought of as the mirror-image of the problem of preserving the viability of the common property grazing land. In this situation there are positive externalities to each person's contribution to the maintenance of the system. In an irrigation system where a member's allocation of water is a fixed share or proportion of the total supply, labor provided by a single individual to increase the supply will not only benefit him but benefits all other farmers as well. At the same time, one person, alone, cannot do enough work to assure himself an adequate supply. A certain threshold level of labor is required to maintain the flow in the system. There are possiblities of free riding, i.e., getting the benefits of others' work in maintaining the system without participating oneself. An individual's willingness to provide his labor to maintain the system is influenced by his expectations regarding the other members' behavior. This is especially true if an individual's sense of fairness results in him experiencing disutility if someone else gets something for nothing, i.e., does not contribute his labor but still is able to irrigate.[15] If an individual's expectations are that the other members will also work to maintain the system, resulting in benefits to him, he will be more likely to provide labor which will not only benefit him but the others as well. Institutions that will provide this assurance are, thus, logical endogenous responses in the face of this uncertainty (Runge, 1981). Examples of such institutions are the requirement that members contribute labor in proportion to their water

---

[15]This type of attitude was heard voiced by residents of Argali several times. People said that if someone who did not contribute to a project would benefit from their efforts, they would not make the investment <u>even though their own benefits would exceed their costs</u>. This has been referred to by Norman Uphoff as the "spite factor," i.e., cutting off one's nose to spite his face (personal communication).

allocations, the maintenance of written attendance records, and fines for absences.

Not only are a farmer's expectations about the probabilities of others supplying the labor to acquire the water important, his expectations concerning their behavior relative to the distribution of the water are also relevant. This behavior determines whether he will obtain the fruits of his labor or whether the benefits will be disproportionally appropriated by others. The rules concerning the distribution of water, whether by saacho or rotation, as well as sanctions for interfering with the accepted pattern of distribution, evolve to provide the assurance that the members' contributions to maintaining the system will benefit them.

In this chapter the security aspect of the institution of property rights in water has been explored. The customary tradition of water rights and the irrigation system management organizations with their rules for resource mobilization, water allocation, and water distribution are institutions which have evolved to define the property relationships among groups of farmers and individuals. They define the rights and obligations of different people with regard to both water and the physical irrigation works, and by doing so provide the security of expectation needed to encourage the significant levels of investment required to develop, operate, and maintain irrigation systems.

CHAPTER 7: WATER ALLOCATION: THE FLEXIBILITY FACTOR

In the preceding chapter, the focus of the discussion was on the security that the institution of property rights in water provides to investors who develop and maintain an irrigation system. It does so by providing assurance of expectations concerning the behavior of other persons, both those who share in the property rights and those who do not, thus ensuring that the owners will receive the benefits of their investments in the irrigation system. In Nepal, as in many other places (Maass and Anderson, 1978), the appropriative rights in the source of supply under the doctrine of prior appropriation belong to the irrigation organization, and in the previous chapter the emphasis was primarily on these property rights held collectively by the members of the organization. The way in which the rules and sanctions of the organization regarding resource mobilization and water distribution contribute to increasing the security of individual members' investments in the system and their access to the benefits was discussed as well. The focus in this chapter shifts to the principle by which the collective property rights of the organization are allocated among individual farmers. An important aspect of this element of the system of property rights is the means by which persons without rights to the water can acquire them.

After an irrigation organization secures the rights to a certain amount of water in a source by constructing a diversion and main canal, two water allocation issues remain. First, as was discussed in Chapter 6, the organization must often limit the expansion of the area that is irrigated because there is not enough water in the source to effectively irrigate the entire hydraulic command area, i.e., it must restrict access to the water in the system in some way.

Second, an irrigation organization must, also, somehow allocate the water quantitatively among its members and, in some cases, nonmembers. The water allocation principle specifies how, or on what basis, the water rights are distributed among the members of an irrigation organization. It also determines how people can gain access to the water of an irrigation system. This becomes particularly important if the system is improved to supply more water.

The farmer-managed irrigation systems in Nepal are dynamic. A system initially delivers only a small amount of water and may be vulnerable to frequent interruptions of supply because of floods which wash away the diversion, landslides which block the canal, and crude drainage crossings which are easily washed out. Gradually improvements, such as enlarging the canal, digging tunnels for the water to pass underground through landslide-prone areas, constructing a more permanent weir which captures more of the water, etc., are made. Of particular importance to the efficiency and equity of resource use is what happens after improvements are made to an irrigation system which result in an increase in the volume and/or reliability of the water supply. Is the use of this enhanced supply of water limited to the land that had been irrigated prior to the improvements, enabling the original member farmers to reduce their efforts in managing the water since they have more of it? Or does the principle of water allocation provide a mechanism for allowing additional land to be brought under irrigation and more farmers to join the organization? Different principles of water allocation yield different results in such a situation. Thus, we can see that the water allocation principle has significant implications for the efficiency of resource use as well as for equity.

7.1 Theoretical Considerations

When considering the need to provide incentives for investments through institutions which protect the investor's access to benefits from the investment, it is important to differentiate between "rigidity" and "security" in water rights. Rigidity, in the sense that new users who would put the water to more productive uses than the current ones are denied access to the water, is not desirable from an economic efficiency standpoint. Security, which will encourage the holder of water rights to develop the resource to the economic optimum, does not require this type of rigidity. All that is required is that a shareholder be compensated for his investment in water supply development and for foregone revenue if his right is transferred to another (Ciriacy-Wantrup, 1955).

The achievement of efficiency in the use of irrigation water "requires institutions that can forge a particular balance between flexibility, which is necessary if water is to be transferred from less to more efficient uses, and certainty, needed if farmers are to make the investments of labor and capital that are consistent with economic growth" (Maass and Anderson, 1978:6). Chapter 6 examined the certainty or security aspect of property rights in water. The focus of this chapter is the degree of flexibility of different principles of water allocation.

Transferability is one of the characteristics of a non-attenuated structure of property rights,[1] and a non-attenuated structure of property

---

[1]Attenuation of property rights is said to occur when restrictions are imposed on the uses to which an asset can be put and/or on the freedom of the owner to transfer rights in the asset to others (Furubotn and Pejovich 1974).

rights has been shown to be necessary for economic efficiency (Randall, 1975). In order to achieve efficiency in the use of water, marginal units of irrigation water must be allocated to those farms which will produce the greatest net benefits. This may require the transfer of water among farms within the irrigation system, i.e., among those already holding water rights, or to farms outside of the system which currently do not have an allocation of water. Some water allocation principles facilitate these transfers while others inhibit them.

Water rights can be transferred in various ways both voluntarily and involuntarily. In terms of both the number of transactions and quantity of water involved, involuntary transfers have probably been more important than voluntary ones (Ciriacy-Wantrup, 1964).[2] Usually states reserve the ultimate right to transfer water rights. Transfers may be accomplished through "condemnation" or "prescription." Condemnation for public use normally requires compensation, but in the absence of a market for water rights, establishment of a rate of indemnification that leads to economically efficient levels of investment in the development of water resources is unlikely. Transfer by prescription does not involve compensation and thus inhibits economic efficiency.

Probably the most common form of voluntary transfer of water rights is in conjunction with land transactions. In many irrigation systems, the water rights are appurtenant to the land, and the allocation of the rights is in proportion to the area of one's holdings relative to the total area irrigated. Land that has a water allocation cannot be sold without the water, and

[2]While this statement was made with regard to the United States, it likely is true in general. Unless there is a well-functioning water rights market in which the true opportunity costs of the rights are reflected, people are unwilling to give up voluntarily a valuable resource such as water.

transfer of water rights separate from the land to which they are attached is prohibited. This tying of the water right to the land represents an attenuation of the property right in water which can result in a less than efficient utilization of the water. In the absence of perfect factor markets and particularly where employment opportunities are extremely limited, resulting in a very low opportunity cost for household labor, the same proportions of land, water, and management (labor) will not be equally efficient on all farms. Some farmers might have excess labor which they could use to manage a lesser amount of water more efficiently, while labor-scarce farmers would find it more efficient to use more water per unit of land. Having the property rights in water tied to the land prevents transfers among farmers that could result in a more efficient utilization of the water.

If water use is to be flexible and transferable, the water right must be mobile, and this rigid appurtenancy of the right to specific land is undesirable from both efficiency and equity considerations. Water may not be put to its most productive use, and access to water is limited to those who are able to purchase land that has a water right. People owning land adjacent to an irrigation system might be able to gain access to irrigation if there were a market in water rights separate from the land. However, the purchase of land with water rights is often beyond their means.

Allocative efficiency in the use of water is achieved when, following transfers of water, it is no longer possible to move another unit of water from one user to another where it would produce more value than the costs of moving it. Included in the costs are the conveyance costs of moving it to another location plus the income from the water in its former use which would be foregone, i.e., full opportunity costs. If it is possible to store the water for use in another season, the present value of any future use foregone must also be considered. In such a case there is not only a spatial dimension to allocation but also a temporal one (Gardener, 1981). Without a market in which water rights can be bought and sold, the owner of water rights will not be aware of the opportunity cost of his use of the water. Even if he were aware that water might have a higher value in an alternative use, in the absence of transferability this will make no difference in his use of the water. He will not be able to sell water rights and capitalize on these higher valued uses (Anderson, 1983).

An irrigator with water rights will continue to use more water (up to the limit of his right) as long as the marginal benefits of using the water exceed his marginal costs. In the absence of a market, these costs that the user considers will be less than the social costs of using the water. This is because they will not reflect the benefits foregone by not using the water in another place, i.e., the opportunity cost. An irrigator may substitute water for management (labor) because the water is less costly to him. However, at the level at which he is applying water, its value of marginal product may be less than it would be on a nearby farm which does not have access to irrigation. If there were a market in water rights, and if the value of the marginal product of the water on the fields of the farmer who has no water rights exceeds the conveyance cost plus the cost of additional management required by the original farmer to maintain his current level of production with less water, the two could enter into a mutually beneficial transaction involving some of the water.

A smoothly functioning water rights market would allow for the easy transfer of water among users. A farmer owning water rights would be continually presented with bids for his water, and these bids would inform him of the opportunity cost of using the water. He would be induced to economize in his use of water and to sell off some of his water rights if another farmer placed a higher value on them (Tregarthen, 1977).

Ideally, transactions in water rights could be in any amounts and for any duration, from the permanent sale of the right to the temporary transfer of the right for a single season or even the amount of water or fraction thereof that is delivered to a right in one rotation turn. The latter two types of transfers could be accomplished through a rental market. These types of transactions would allow for the equalization of the value of marginal products across users, a requirement for efficient allocation. Rarely, however, does such a well-articulated market in water rights exist. One reason that it does not exist is the the rather complex nature of water as a fluid resource. "Rights in water are harder to define and to observe than, say, rights in basketballs" (Tregarthen, 1977:150). Buyers and sellers face a great deal of uncertainty as well as high information costs in determining exactly what is for sale. "Fluctuations in supply and the complexity of hydrological characteristics introduce considerable uncertainty into the allocative function of the market for water" (Tregarthen, 1983:120). Water, because it moves, creates positive and/or negative impacts, i.e., externalities, on others before, during, and after its use. According to Gardner (1981:68), "It is this fugitive character of water that perhaps has made society reluctant to endorse private ownership and control."

Maass and Anderson (1978) assert that markets for renting water rights for a season or rotation turn are much more prevalent than markets for the permanent transfer of water rights. According to them this is because of the "popular belief that to allow easy transfer of water, more so than of other means of agricultural production, is to invite foreign control over farmers' activities and that such control necessarily would be antagonistic to community objectives" (1978:376).

Much of the economic literature on water allocation assumes that a central irrigation agency owns the irrigation works and water rights. At issue then is how the agency should allocate the water among farmers to achieve efficiency in use of the water. The conclusion is that to satisfy the objective of economic efficiency, the price system should be the mechanism for allocating irrigation water among competing users. Those users for whom the value of the marginal product of additional water is greatest will be willing to pay the highest price for it. To the extent that water is not rationed in accordance with willingness to pay, it will not be consumed most profitably (Marglin, 1966).

Actually implementing allocation by price for gravity-flow irrigation systems, however, is difficult, and there are few examples of it. In order to allocate water by the price system, it is necessary to charge for each unit used. This requires relatively accurate volumetric metering of the delivery to each user, if users are to be convinced that they have actually received the amount for which they are billed. Charging for water on some other basis than the amount used, such as a charge per area irrigated--a common method of charging--does not promote efficient water use and, in fact, contains incentives for inefficient water management. Having paid the fixed per- hectare fee for water, the farmer faces little, if any, marginal costs in the use of water. To the extent that he can get more water, he has an incentive to substitute water, which is cheap in terms of marginal costs to him, for labor that would be needed to manage water more efficiently. However, volumetric metering of water is costly to implement and administer, and, thus, allocation of water according to the price system has seldom been practiced. The major exception to this is well irrigation where it is easier to meter the water. Since a constant flow rate can be maintained, the length of time that water is delivered to a farmer from the well is a good proxy for the actual volume of delivery. Water from gravity-flow canal systems administered by government irrigation agencies is most often allocated in proportion to the area irrigated. Distribution may be either by continuous flow or timed rotation, and an attempt is made to supply water in proportion to the area irrigated either through the adjustment of gate openings or the setting of the length of time of turns. Fees, if they are charged, are usually on the basis of area irrigated.

7.2 Methods of Water Allocation

Having discussed the theory of efficient water allocation, let us turn to an examination of different methods of water allocation. Most of the analysis of water allocation principles has involved the modeling of irrigation systems using different allocation schemes. Maass and Anderson (1978) in their work on irrigation systems in Spain and the western United States have described and analyzed a number of methods by which water is allocated within irrigation systems. Their analysis includes six different methods that are applicable to the run-of-the-river diversion systems such as were studied in Nepal. Another method, requiring storage reservoirs, will not be considered here.[3] The relevant methods include:

1. Farm Priorities (Allocation by Prior Appropriation). Farms are served in an order of priority. This priority is typically based on the time or order of settlement, and this can, thus, be viewed as an extension of the principle of prior appropriation to the individual farms within the system.

---

[3]Under this method the supply for the whole season is stored and available at the beginning of the season. Farms are allotted a fixed quantity for the season and can take it when they want it; hence it is called distribution according to "demand." But the allocation is a fixed proportion of the water that is stored in the reservoir at the beginning of the season.

When water reaches a farm, that farmer can take all that he wants before the farmer next in the order of priority receives any water.

2. Turns (Allocation by Location). Farms receive water in order of their location along the canal. As above, when water reaches a farmer, he takes all that he wants at that time before the next farmer along the canal is served. While the order might proceed from tail to head or from head to tail, if it is from head to tail, this could be seen as an extension of the riparian doctrine along the canal. The head or "upstream" farmer can meet his needs before the "downstream" farmers receive water.

3. Shares (Allocation in Proportion to Area Irrigated or by Purchased Shares). Each farm receives a fixed percentage of the supply. The supply is distributed continuously, and all farms share proportionally in any variations in the supply.

4. Rotation (Allocation in Proportion to Area Irrigated or by Purchased Shares). Under this method each farm receives water for a fixed period of time. The length of each farm's turn is assigned to provide a proportion or share of the supply as in number 3, but the amount delivered in a turn will vary according to the fluctuations in flow in the system. Unlike number 3, this variation will not be shared by all farms.

5. Crop Priorities (Allocation to Crop). An order of priority for different crops is established. This may be based on economic value, but may be determined by other considerations such as government policies mandating production of certain amounts of specific crops. If water is plentiful, all crops will be irrigated, but if it grows scarce, crops will be served in order of priority, and some will not receive water.

6. Market (Allocation by Price). Under this procedure, irrigators bid each period for the water to irrigate their crops. It should be allocated to the highest value uses because these farmers can outbid those who would apply it to lower valued uses.

The principle by which the shares of the water are apportioned under 3 and 4 (shares and rotation) is often in proportion to the area of a person's land relative to the total area irrigated. It may, also, be on some other basis such as shares purchased in the system. The principle by which these shares are allocated has important implications for equity and efficiency as shall be discussed later in this chapter.

Maass and Anderson developed two simulation models, one to represent systems in Spain and the other systems in the western United States, to evaluate the efficiency and equity of the different principles of water allocation mentioned above. They simulated each allocation principle and for each ran the model with 90 and 75 percent of the water supply needed to achieve "full production of the crop acreages that are planted" (1978:376). The different principles were evaluated by comparing the net income they produced under the given water supply conditions with a benchmark run having sufficient water for all farms to achieve full production. In efficiency terms, the best allocation principle is the one for which the loss function, i.e., the difference between the net income under full production and that with the reduced water supply, is minimized. Allowing for buying and selling of water in the market ranked the highest of the allocation methods in terms of efficiency. The market method of allocating water also resulted in the most equal sharing of losses in net income when the supply was reduced.

Glick (1970) has identified two types of allocation principles for distributing the rights to water within an irrigation system. The one he terms the "Syrian type" is characterized by water rights being attached to the land and distributed in proportion to land area. The other, termed the "Yemenite type," is based on fixed time measurement units and rotational distribution and incorporates the sale of water. He finds the two types to be suitable under different environmental conditions. The "Syrian type" is found in areas where water is plentiful, and the "Yemenite type," where it is scarce (Glick, 1970:368). This is not surprising since water will have a higher value where it is relatively scarcer, and it is argued that allowing the transfer of water rights through sales permits a more efficient allocation of the scarce water.

Most studies which compare different principles of water allocation arrive at the same conclusion, i.e., that a system of marketable water rights is more efficient than other non-market methods of allocating water. Wong and Eheart (1983) compare two systems of marketable rights and two non-market methods of allocation. Their analysis considers only the allocation of long-term or base rights and not short-term or spot market transactions. The two different types of marketable rights are the "fractional flow right" (FFR) and the "prioritized steady use right" (PSUR). The FFR entitles users to a fraction of the available flow, and all users have equal priority under this type of right. PSUR entitles users to consumption of a fixed amount of water on a priority basis (Eheart and Lyon, 1983). This is similar to the doctrine of prior appropriation. The model allows for a one-time transfer of these base rights through different types of auctions. Two non-market principles of allocation are compared with these. One is allocation in proportion to area irrigated with no provision for transfers. In the other scheme, termed "feast or famine," all farmers are allowed to withdraw whatever amount of water they want up to a certain maximum if there is adequate supply to provide for everyone; otherwise, no one is permitted to take any water. The two market systems of allocation achieve nearly 95 percent of the optimum aggregate annual worth. Inclusion of a spot market for transfer of short-term rights would allow for more flexibility of allocation and the achievement of results even closer to the optimum. Allocation in proportion to area irrigated without allowing for transfers achieves 84 percent of the optimum, while the "feast or famine" principle results in only 53 percent of the optimum.

Huszar and Sabey (1978) analyze the impact of the transferability of water rights on area irrigated, value of irrigated crops, and the amount of water pollution resulting from irrigation return flows (i.e., water returning from fields to streams and rivers). Return flows, including seepage, deep percolation, and surface runoff, pick up pollutants such as salts, sediments, nitrates, and phosphates as water moves over and through the soil. The higher the rate of water application, the higher the amount of pollutants that is carried by the return flow into the stream. A model based on the Yakima Valley of Washington is used for the analysis. With the introduction of a water rental market, there is an opportunity cost for the holder of water rights in his use of water, and he will reduce the amount he uses and rent some to others who have either no water rights or less than they can use profitably. By making possible the profitable transfer of water, a water rental market would result in an expansion of the area irrigated and an increase in net income in the Yakima Valley as well as, due to lower water application rates, a reduction of the water pollution returning to the river.

With a case study of Egypt, Bowen and Young (1984) have analyzed the effects of alternative methods of charging for irrigation water. They have modeled different area-based and volumetric approaches to charging for water and analyzed the impact on efficiency and equity objectives. An explicit attempt was made to estimate the transactions costs of the different charging methods. The results show the importance of transactions costs in determining an efficient mechanism for assessing charges. Under relatively plentiful water supplies, area-based charges are satisfactory because of the high cost of volumetric metering and the relatively low value of the water. However, when scenarios involving serious water shortages are modeled, the results show that volumetric methods of charging are more efficient and equitable.

7.3 Initial Allocation of Water Rights

While allowing water rights to be allocated by buying and selling in a market will generally lead to the most efficient allocation of water, the method by which the initial allocation is determined has important implications for equity. "The initial assignment of property rights, together with the initial endowments of abilities and interests, determine the distribution of wealth in the economy" (Tregarthen, 1977:143). The rights to use water represent valuable assets, and their initial allocation ought to further society's goals with respect to the distribution of wealth. When irrigation systems are developed and water is allocated to specific land, this benefits an already relatively better-off class, the landowners, more than it does the poorer class of landless. There have been some limited efforts to achieve greater equality in the initial assignment of water rights. The Sukhomajri Project in Haryana, India, allocated equal shares of rights in the system to each household in the village including the landless (Seckler and Joshi, 1981). The landless and those with rights to more water than they needed for their small landholding could rent water to households which had more land and insufficient water.

The Andhi Khola Project, an irrigation and hydroelectric project being constructed in Nepal, is attempting a similar allocation of water rights on a larger scale (Thiessen, 1983). Local people, irrespective of whether they own land or not, will be able to earn shares in the system by donating their labor for construction of the conveyance and distributary canals. There will be an upper limit to the number of shares a household may own. A rental market will enable farmers who have more land than they can irrigate with the water acquired through their shares to rent water from landless or near-landless farmers. Landless households may be able to exchange a portion of their water rights for usufruct rights in land owned by households with large landholdings. The direct benefits of the irrigation project will, thus, be spread beyond those households fortunate enough to own land in the project's command area, a more equitable distribution of benefits.

7.4 Water Allocation in Farmer-Managed Irrigation Systems in Nepal

In most of the farmer-managed irrigation systems in the hills of Nepal, water is allocated within an irrigation system on a proportional basis. These are what Coward (1985a) terms "share systems." One's property rights in water are explicitly defined in units that represent a fixed proportion of the total water supply in the system. This fixed proportion is maintained as the total supply fluctuates up and down, and the amount of water represented by a share varies accordingly. In Nepal, as in irrigation systems in much of the world, the most common means of allocating the shares is in proportion to the area that is irrigated. If, for example, an Argali farmer's land consists of five percent of the area that is irrigated, he is entitled to five percent of the water supplied by the system. In systems in which water is allocated in this manner, the water rights are appurtenent to the land. An interesting question pertaining to systems with this principle of water allocation is how the total area with water rights was determined and delineated in the first place.

Another observed but much less common means of allocating the water in a system is through sales of shares, i.e., a market in water rights. A purchased share entitles the owner to a fixed proportion of the system's supply. In the Chherlung Thulo Kulo system with 60 shares, one share represents one-sixtieth of the flow in the system at any time. In irrigation systems with this principle of water allocation, water rights are not tied to any specific parcels of land, and transactions in water shares can and do take place independent of land transactions.

These two principles of water allocation represent two different structures of property rights. The arrangement of property rights is a substantial component of the structure of incentives which guide economic choices and, as such, affects the efficiency of resource allocation (Randall, 1975). The two different principles of water allocation provide farmers with different incentives for managing water and, thus, influence the efficiency of water use. The effect of the principle of allocation on the efficiency and equity of water use will be analyzed by comparing the irrigation systems in Argali, which allocate water in proportion to land area, with those of Chherlung, which allocate water by purchased shares.

7.5 Argali: Water Allocation in Proportion to Area Irrigated

7.5.1 Seasonal Differences in Allocation

When analyzing the principle of water allocation in Argali, and Chherlung as well, it is necessary to distinguish the season because allocation rules are not the same in each season. The irrigation systems were developed initially to irrigate a monsoon rice crop, and it is for this season that the water allocation is most precisely defined and restricted. The Raj Kulo irrigation organization is a strong and effective organization which has solved the problem of growth that Maass and Anderson (1978) emphasized as being necessary to sustain a viable system. During the monsoon season, irrigation is limited to about 47 hectares, and rice is cultivated on all of this. The fields covering these 47 hectares have been terraced, leveled, and bunded, i.e., made into <u>khet</u>, for flooded irrigation of rice. Membership in the Raj Kulo organization is limited to the households farming these 47 hectares.

In the winter season, the primary crop is wheat, with some potatoes, cabbage, and cauliflower also being grown. Because these crops require much less water than rice, the irrigated area in the winter is more than double the area of the monsoon rice crop, even though the supply in the system is considerably less than during the monsoon. While first priority for using the water in the winter is reserved for the khet fields, anyone farming land within the hydraulic command area of the Raj Kulo system is permitted to use its water for irrigation in this season, and approximately 102 hectares are irrigated. Of this, just over 50 hectares are bari. These approximately 50 hectares of bari are also allowed one irrigation for planting of a pre-monsoon maize crop in April or May.[4] Soon after the planting of the maize crop, seedbeds for the monsoon rice crop are established on the khet, and these then have priority rights to the water. The maize on the bari does not receive any irrigation after planting.[5]

The discussion and analysis of water allocation will be limited to the allocation of rights to the water for the monsoon season. It is in the allocation of water in this season that there is a significant difference between Argali and Chherlung with implications for efficiency of resource use. In the irrigation systems in Argali, the amount of water to which each field with an allocation is entitled has been defined in terms of its area relative to the total irrigated area. This was reported to have been fixed when the irrigated land was measured and registered by the government for tax purposes.[6] As was described in Chapter 3, the unit of area measurement

---

[4] In Chherlung, also, farmers who are not members of the system are permitted to irrigate the winter wheat crop and for planting of the pre-monsoon maize crop on their bari fields.

[5] Our landlord had a bari field which he irrigated for wheat and for planting maize from the Raj Kulo system. When planting the maize, he filled in the field channel which supplied irrigation to his, as well as some of his neighbors', bari fields and planted maize in it as well. Since the channel would be dry until after the following monsoon season, he chose to expand slightly the area on which the maize was grown by planting in the channel.

[6] This measurement and registration of the land was said to have been done in 1868 (1925 B.S.).

at that time was a maato muri, and each field's allocation is still referred to in terms of "so many muri of water."

7.5.2 Water Allocation and System Expansion

Formerly, the water supply in the monsoon season was hardly adequate for the approximately 47 hectares which are now being irrigated by the Raj Kulo in Argali. Rotational distribution was practiced, and farmers reported that they would sleep in their fields so that they could make sure they received water when it was their turn. Farmers from Rabidas, which is the tail area of the system, would patrol the canal at night to prevent people from Ranuwa and Khutilam, at the head of the system, from stealing water. In the past 25 years or so, the Raj Kulo canal has been significantly improved and now delivers considerably more water with a greater degree of reliability. The canal has been widened, and agris have been hired to dig tunnels at various places so that the water can pass underground out of the danger of landslides.

The water supply is now sufficient for continuous-flow distribution throughout the monsoon rice season.[7] Yet, despite the significant increase in the supply, there has been almost no increase in area of land that is entitled to water. The water rights still reside with the land to which they have been attached for many years. There has been some marginal expansion of the area irrigated on the periphery of the designated area. This has happened when farmers owning khet fields with a water allocation have also owned bari fields immediately adjacent to their khet fields. They have converted some of

[7]During the 1982 monsoon season when the research was conducted, considerable water was observed draining out of the system whenever there was rain.

their _bari_ into _khet_ and are applying their individual water allocation to a somewhat larger area.

Only those farmers with _bari_ adjacent to their _khet_ have been able to expand the area that is irrigated as the supply in the system has been increased and made more reliable. And this expansion has been unofficial and controversial. A dispute over this occurred in the Raj Kulo system. The major portion of this system is divided into two sections called Ranuwa and Rabidas, the names of the hamlets in which most of the farmers with fields in the two parts live. Water is divided equally between the two sections by a proportioning weir referred to as the system's "main _saacho_." Between 10 and 15 years ago, there was a dispute between Ranuwa and Rabidas over the water allocation. The main _saacho_, at that time, divided the water in half on the basis of each section having 700 _maato muri_ of land with water rights. However, farmers from Rabidas claimed that they had 855 _maato muri_ and demanded that the _saacho_ should be recut to give them water for the additional 155 _maato muri_. Ranuwa farmers maintained that the equal allocation had been established on the basis of which fields had water rights. They held that farmers in Rabidas had made new _khet_ without any authorization to do so and remained firm that the allocation between the two areas was to remain equal.[8]

The situation is much the same in the Kanchi Kulo system in Argali. Originally the fields with water rights totaled approximately 8.5 hectares. About 70 years ago, with the permission of the organization, farmers owning _khet_ at the tail end of the system shifted part of their allocation to adjacent _bari_ fields, which they also owned, and converted them to _khet_. The

---

[8]In the summer of 1983 the wooden main _saacho_ was replaced by one made of cement which continues to divide the water equally between Ranuwa and Rabidas.

conditions under which this was allowed are not entirely clear since a small amount of water (4 percent of the total system supply) was also reallocated from the main system to these new khet fields. Older members of the community suggest that the owners of the new khet earned this additional water from the system by doing some major repair work on the diversion and main canal. The khet area with water rights was expanded to 11.3 hectares.

Calculations showed that the water allocation per hectare in the expansion area (i.e., fields from which water allocation was shifted plus converted bari fields) is much lower than that of the original khet area. A total of 44.5 muri of water are allocated to approximately 3.6 hectares in the expansion area for an average of 12.4 muri/hectare. On the remaining 7.7 hectares at the head of the system, the average allocation per hectare is 34.1 muri, approximately 2.7 times that of the expansion area. Since, as was noted earlier, the distribution of water in the Kanchi Kulo system very precisely matched the allocation, this means that the head area received approximately 2.7 times as much water per hectare as the expansion area in the tail. What is particularly interesting to note is that the yields of rice in the expansion area were not significantly less than those in the head, even though the water supply was much less. The mean yield of the sample crop cuts in the head of the system was 3150 kg/ha while in the tail area it was 3040 kg/ha. The standard deviations of the samples were 730 and 790 for the head and tail, respectively. A two-sample t-test at the 5% level does not allow rejection of the null hypothesis that the means of the two samples are equal.

The farmers in the tail area with much less water were able to manage it in such a way that they did not suffer yield-reducing stress, even though they received only 37 percent of the amount of water that farmers in the head applied to their fields. Farmers in the head distributed water by continuous flow throughout the entire season. Because of having the lower water allocation, farmers in the tail needed to change to rotational distribution beginning on day 52 after transplanting and continued in this manner for the remainder of the season. By following a carefully timed rotation calculated to give each field its proportional allocation, the farmers in the tail were able to irrigate all fields adequately. Had they tried to retain distribution by continuous flow throughout the season, it would not have been possible to cover all the fields in the area adequately. The seepage and percolation rate is so high under continuous-flow distribution that the limited supply would have disappeared before the far ends of individuals' fields were covered, resulting in stress and reduction in yield.

This discussion of water allocation and distribution in the Raj Kulo and Kanchi Kulo systems of Argali is revealing of the relationship between the principle of allocation and the efficiency of water use. The fact that farmers in the expanded area of the Kanchi Kulo system could achieve the same yields as those in the head with only a little over a third the amount of water implies that the area that is irrigated could be significantly enlarged without any reduction in production on the original area. Water application rates on the monsoon rice crop were equally as high in the Raj Kulo system as in the head of the Kanchi Kulo system, and farmers said that they could more than double the area irrigated by changing to rotational distribution and would do so if they owned all the land. The principle of allocating water in proportion to area irrigated and tying the water rights to specific plots of land provides no mechanism for expanding the area irrigated as a system's supply is increased, nor does it provide farmers an incentive to use more efficient water management practices. With the improvements to the system which have significantly increased the supply in both the Raj Kulo and Kanchi Kulo systems, the area irrigated has been only marginally increased, legally in the Kanchi Kulo system and without authorization in the Raj Kulo. Instead, those farmers with water rights have been able to reduce the effort they put into water management, changing to distribution by continuous flow instead of by rotation.

7.5.3 Linear Programming Analysis

When the linear programming model developed to represent the Kanchi Kulo system was run in Chapter 4, the area that could be irrigated was limited to the area that is presently irrigated. In order to analyze the optimal allocation of water by this system, the model was again run without constraining the area that could be irrigated. Table 7.1 compares the results of the two runs, area-constrained and unconstrained, using the water supply that was measured.[9] The symbols used in Table 7.1 are defined in Table 7.2.

The result that is of most interest is the increase from 10.7 ha to 19.4 ha in the area that is irrigated when irrigation is not restricted to that land which currently possesses the water rights. Only 1.8 ha of this is irrigated for the entire season by continuous flow. Ten hectares are irrigated by rotational distribution in periods two and three, and 7.6 hectares by rotation in period three only. This compares to the area-constrained model in which seven hectares of the 10.7 hectares area irrigated were supplied by continuous flow for the entire season. The results of the area-unconstrained model show no drainage in any period and a shadow price of water in periods

[9]For this run it was assumed that the amount of land preparation done was the same whether distribution was by continuous flow or rotation. This is the same model formulation as was used to generate the isoquant in Figure 4.3.

1, 2, and 3 of Rs. 225.7, 7.3, and 2.7 respectively. The price of Rs. 2.7 in period three of the area-constrained model represents the substitution of

Table 7.1 Model Results

	Area-constrained	Area-unconstrained
Crop Production		
HY1	7.0 ha	1.8 ha
HY2	3.7	7.6
HY3	0.0	10.0
LY1	0.0 ha	0.0 ha
LY2	0.0	0.0
LY3	0.0	0.0
Supply Enhancing Activities (1 = yes, 0 = no)		
SE1	0	1
SE2	1	1
SE3	1	1
Demand Diminishing Activities		
ROT2	0.0 ha	10.0 ha
ROT3	3.7	17.6
Drainage		
Period 1	146 ha-mm	0 ha-mm
Period 2	0	0
Period 3	0	0
Shadow Price of Water (Rs./ha-mm)		
Period 1	0	225.7
Period 2	2.5	7.3
Period 3	2.7	2.7
Shadow Price of Land (Rs./ha)	7,016	0
Objective Function Value	Rs. 76,797	Rs. 136,490

Table 7.2 Symbols Used in Presenting Model Results

HY1: Unstressed rice crop (yield = 3.5 tons) grown under continuous-flow distribution all season.
HY2: Unstressed rice crop grown with continuous-flow distribution months 1 and 2 and rotational distribution month 3.
HY3: Unstressed rice crop grown with continuous-flow distribution month 1 and rotational distribution months 2 and 3.

LY1: Stressed rice crop (yield = 1.6 tons) grown with continuous-flow distribution all season.
LY2: Stressed rice crop grown with continuous-flow months 1 and 2 and rotational distribution month 3.
LY3: Stressed rice crop grown with continuous-flow month 1 and rotational distribution months 2 and 3.

SE1: Supply-enhancing maintenance, month 1. (1 = yes, 0 = no)
SE2: Supply-enhancing maintenance, month 2.
SE3: Supply-enhancing maintenance, month 3.

ROT2: Number of hectares on which rotational distribution done month 2.
ROT3: Number of hectares on which rotational distribution done month 3.

hired labor for water, while the much higher value of water in the first period of the area-unconstrained model indicates that lack of more water is a constraint preventing additional production. Since the land area to be irrigated is unconstrained in this version of the model, the shadow price of land is zero. By allowing the system to allocate water over the optimal land area, the value of the objective function is increased by Rs. 59,693, an increase of 78 percent over the area-constrained model. This represents the opportunity cost of restricting the allocation of water to the area which currently possesses the water rights.

7.6 Chherlung: Water Allocation by Purchased Shares

The Thulo Kulo and Tallo Kulo irrigation systems in Chherlung both allocate water rights within the system by the sale of shares. Ownership of water rights is independent of land ownership, and transactions in water take place separate from land transactions. When the Thulo Kulo canal was completed and water first arrived in Chherlung, it was allocated to the 27 households who had financed the construction of the canal. Since the shares were allocated on the basis of how much each household had contributed to finance the construction contract, some households' contributions secured for them more water than they needed to irrigate their fields, while other households desired more water. In addition, households which had been skeptical about the feasibility of the project and unwilling to contribute, upon seeing water arrive in Chherlung, decided that they also wanted access to irrigation. At this time the principle of buying and selling shares was established, and it has continued as the method of water allocation. The price of shares is set and periodically revised by the organization's management committee. In the same way that the original price reflected the initial cost of construction, the price continues to be set with consideration of an estimate of the total investment in the system.[10] Table 7.3 presents the selling price of a share of water since the beginning of the system as recalled by the chairman of the organization.

[10]It was reported, however, that amounts considerably in excess of the price set by the committee are frequently paid in private transactions which would approximate the free-market price of water.

Table 7.3 Selling Price of a Water Share Set by the Thulo Kulo Management Committee

Year	Price/share (Rupees)
1932	100
?	150
?	200
?	250
1958	500
1967	1000
1977 [a]	2800
1982	4000

a. In this year, the organization sold ten additional shares in the system, bringing the total number of shares to sixty.

7.6.1 Types of Transactions

Two types of share transactions are conducted. The most common are those between two individual farmers. The purchasing farmer may be one who previously had no shares in the organization or one who had less water than he wanted to irrigate his fields. Sellers are farmers who have decided they can manage with less water than their shares represent and are willing to part with some at the going price. Since the system has been continually upgraded ever since its original construction,[11] the amount of water delivered by the system has been increased considerably. Thus, because a share is a fixed proportion of the flow in the canal rather than a specified discharge or volume of water, over time it has increased in the amount of water that it represents. With a share delivering more water than it had before improvements were made, an area that at one time had required a full

[11]The agris who were contracted to do the original construction were retained for an additional four years to improve and maintain the canal.

share for irrigation at a given level of management can now be irrigated adequately by less than a share if the same level of on-farm water management is continued. Alternatively, the level of management applied by the farmer in irrigating his fields can be reduced, and irrigation with the share will still be adequate.

A farmer has several incentives to reduce the number of shares that he owns as the amount of water in the system is increased. Because there is a market for selling water shares, he is made aware of the opportunity cost of his use of water. By maintaining or improving his on-farm water management so that he can achieve his desired adequacy of irrigation with fewer shares, he can acquire scarce cash by selling shares. Since resources for maintaining and improving the system are mobilized in proportion to the members' shareholdings, selling some shares also reduces the amount of annual investment that he is required to make. The amount of resources mobilized by the Thulo Kulo organization each year is quite high, as shown in Chapter 3, so this is not an insignificant incentive factor. As long as the income from sale of a share plus the expected net present value of resources that the farmer will no longer have to invest in the system exceeds the net present value of any additional effort needed for on-farm water management with a smaller supply plus any yield reductions because of having less water, there is an incentive to sell shares.

The second type of share transaction involves sales by the organization. In the event that no individual is prepared to sell, persons wanting to buy shares can approach the organization which may agree to sell. This requires increasing the number of shares in the system with the result that each share will represent a smaller fraction of the supply. In Chherlung, the one time that this happened was in 1978. A group of farmers wanted to buy water to begin irrigating a sizeable new area in the tail of the Thulo Kulo system. No single individual could have sold them enough shares to make this feasible, so the farmers, some of whom were already members of the organization, requested the organization to sell them shares. The organization decided to increase by ten the number of shares in the system, i.e., an increase from 50 to 60, and to sell them at the rate of Rs. 2800 per share. Twenty-eight farmers bought the ten shares with individual purchases ranging from one-sixteenth to five-eighths of a share. The Rs. 28,000 raised by the sale was invested to make improvements in the canal to deliver more water in order to serve the additional area.

There is not a well-developed rental market for exchanging water shares temporarily for a season while retaining ownership of the basic right. In 1982, one farmer rented out his water share during the monsoon season. He had sold his khet land but had retained some of his water in anticipation of purchasing khet in the future. The income he received from renting was about four percent of the selling price.

7.7 Comparative Analysis - Efficiency

The principle of allocating by purchased shares accomplishes two functions relative to the size of the area that is irrigated. It satisfies the need, highlighted by Maass and Anderson (1978), for an organization to have a means of controlling the growth of the system. Shares will only be transacted as long as the seller retains the amount of water that he wants to irrigate his fields and the buyer acquires sufficient water to supply the amount of land that he wants to irrigate. No other arrangement is needed to control the growth of the system. At the same time, this principle of water allocation provides a mechanism for expanding the area that is irrigated as supply-enhancing improvements are made to the system. Individual farmers have incentives to sell shares, allowing for expansion, and the organization is prepared to accommodate the expansion. Bari land in Chherlung has been rapidly converted to khet as the system has expanded to irrigate nearly the entire hydraulic command area. Nearly 85 percent of this area has been converted to khet compared to only 45 percent of the Raj Kulo system's command area. The chairman of the Thulo Kulo organization estimated that the area irrigated during the monsoon had doubled between 1967 and 1982 as a result of continual improvements to the system and subsequent sales of shares.

In Argali as the systems have been improved to deliver a greater water supply, the organizations have been able to shift to less management-intensive, continuous-flow distribution because the irrigated area has not been enlarged significantly. The situation is different in Chherlung. Both the Thulo Kulo and Tallo Kulo systems have been upgraded considerably over the years and the supply has been increased. However, in these systems, the incentive structure provided by the institution of allocation of water by purchased shares has resulted in an expansion of the area irrigated and retention of more intensive management of distribution. Water is distributed continuously from the main canal to the secondaries by the use of saachos. In contrast to Argali, water within the secondaries is distributed to farmers' fields by means of a strict timed rotation.[12] Comparison in Table 7.4 of the net relative water supply (NRWS) computed in Chapter 5 for the Raj Kulo and

[12]Early in the 1982 monsoon season, the supply was observed to be sufficient to allow for distribution by continuous flow, but beginning in the eighth week after transplanting it was necessary to shift to rotational distribution.

Kanchi Kulo systems in Argali[13] and the Thulo Kulo and Tallo Kulo systems in Chherlung shows the latter two using a lower supply per demand than the systems in Argali. Yet none of the systems exhibited any evidence of yield-reducing stress due to insufficient water supply,[14] indicating that by using more intensive water management, Chherlung farmers were able to achieve the same level of output. This is additional evidence that allocation by purchased shares leads to more efficient use of water than allocation in proportion to area irrigated.

Table 7.4 Net Relative Water Supply in Argali and Chherlung

System	NRWS	Allocation Principle
Raj Kulo, Argali	1.34	Proportional to Area
Kanchi Kulo, Argali	1.35	Proportional to Area
Thulo Kulo, Chherlung	0.99	Purchased Shares
Tallo Kulo, Chherlung	0.90	Purchased Shares

7.7.1 Linear Programming Model Analysis

Allocating water by purchased shares is an institutional innovation that allows for an allocation of resources in irrigated agriculture that more nearly approaches the optimal than does allocation in proportion to area

[13]The Maili Kulo and Saili Kulo systems are not included in this comparison because they are land-constrained systems, i.e., there is no additional land that could be irrigated by them even if the allocation principle permitted expansion.

[14]Yoder (1986) found evidence of some yield-reducing stress in the tail area of the Thulo Kulo system. This could not be attributed to a systematic shortage of water in that part of the system because some fields with lower per-hectare allocations of water experienced less stress than ones with higher allocations. It was concluded that the yield reductions were a result of less intensive field-level water management by farmers who lived some distance from the fields in this part of the system. They likely missed some turns in the rotation schedule by not making the trip to their fields when it was their turn to receive water, particularly when their turn happened to be at night.

irrigated with water rights tied to the land. The linear programming model developed in Chapter 4 was modified to analyze the impact of allocating water by purchased shares on the productivity of the irrigation water. The purpose is to analyze what would happen if the water in the Kanchi Kulo system of Argali were allocated by purchased shares instead of in proportion to area irrigated. For this, the irrigation system is divided into two sections, a head and a tail. The head area is defined as the 10.7 hectares used in the original model formulated in Chapter 4. The area in the tail is not limited, i.e., through water purchases and intensive management, it is allowed to expand until the available water is a constraint. Technical coefficients in the two sections are assumed to be identical. The outline of the model consists of two blocks like that in Table 4.2, with one representing the original 10.7 hectares and the other the area in the tail to which irrigation can be extended. A water-selling activity is included in the head and a water-buying activity in the tail block.

To establish how much water the head-area farmers would sell, the model was first run with only production in the head and income from water sales contributing to the objective function. Since the income in the model is the net value of one year's rice production and not the net present value of production over the life of the system, the price of water in the model is the annual interest on the selling price of a share. Assuming an interest rate of ten percent and the current official Thulo Kulo organization selling price of Rs. 4000 per share, this amounts to Rs. 400 per share.

To establish how many shares there should be in the Kanchi Kulo system, a calculation was made of the number of ha-mm of water represented by a share in the Thulo Kulo system in Chherlung. Since the only period in which all of the water was used in the model in Chapter 4 was the third one, the flow in the Thulo Kulo system in the third period was used in the calculation. On the average in the third period, a share in the Thulo Kulo system represented 20.3 ha-mm/day. The average daily discharge of the Kanchi Kulo in the third period was 584 ha-mm/day, the equivalent of 29 shares.

Table 7.5 compares the results in the head area with and without sale of shares at the base water supply, i.e., the measured supply. The without-selling case is the same as the area-constrained case in Table 7.1.

As reported in Table 7.5, running the model with the objective function being the maximization of income from the monsoon rice crop plus the interest on the capital represented by the sale of shares in the system resulted in the sale of 13.1 shares to the tail-section farmers. The model was then run allocating 15.9 shares to the head-end farmers and 13.1 to the tail-enders, totaling the 29 shares calculated above for the system. Given the option of selling shares, farmers chose to do more intensive water management. Distribution was by rotation on 5.6 hectares in period two and 9.7 hectares in period three. Table 7.6 presents the results for each of the two sections and the system as a whole.

Table 7.5 Model Results, Head Area: With and Without Selling Function

	Without Selling	With Selling
Crop Production		
	HY1 7.0 ha LY1 0.0 ha	HY1 1.0 ha LY1 0.0 ha
	HY2 3.7 LY2 0.0	HY2 4.1 LY2 0.0
	HY3 0.0 LY3 0.0	HY3 5.6 LY3 0.0
Supply-Enhancing Activities		
SE1	0	1
SE2	1	1
SE3	1	1
Demand-Diminishing Activities		
ROT2	0.0	5.6
ROT3	3.7	9.7
Drainage		
Period 1	146 ha-mm	0 ha-mm
Period 2	0	0
Period 3	0	0
Shadow Price of Water (Rs./ha-mm)		
Period 1	0	15.0
Period 2	2.5	7.3
Period 3	2.7	2.7
Shares Sold	0	13.1
Shadow Price of Land	7,016	6,565
Objective Function Value	76,797	81,845

Table 7.6 Model Results After Sale of Shares

	Head Section	Tail Section	Total System
Crop Production (Ha)			
HY1	1.0	0.0	1.0
HY2	4.1	4.1	8.2
HY3	5.6	4.6	10.2
	10.7 ha	8.7 ha	19.4 ha
LY1	0.0	0.0	0.0
LY2	0.0	0.0	0.0
LY3	0.0	0.0	0.0
Supply-Enhancing Activities			
SE1	1	1	1
SE2	1	1	1
SE3	1	1	1
Demand-Diminishing Activities (Ha)			
ROT2	5.6	4.6	10.2
ROT3	9.7	8.7	18.4
Drainage (Ha-mm)			
Period 1	0	0	0
Period 2	0	0	0
Period 3	0	33.4	33.4
Shadow Price of Water (Rs./Ha-mm)			
Period 1	235.5	221.4	
Period 2	7.3	32.3	
Period 3	2.7	0	
	Shares Sold	**Purchased**	**Transacted**
	13.1	13.1	13.1
Shadow Price of Land			
	0	0	0
Objective Function Value			
	81,845	58,996	140,841

With a water selling function included, the total area irrigated is 19.4 hectares--10.7 in the head end and 8.7 in the tail. With the exception of one hectare in the head area where continuous-flow distribution is practiced all season, distribution is by rotation, on 9.7 hectares in period 2 and 18.4 hectares in period 3. The contribution of the tail-end area which was able to buy water shares to the objective function is Rs. 58,996 and the total value of production less cash expenses is Rs. 140,841. Thus, allocating water through the sale of shares allows the area irrigated to expand by over 80 percent over what it was with the water allocated in proportion to area irrigated. The net value of production from the irrigation system increases by 83 percent over what it was in the area-constrained case in Table 7.1. Rice production from the irrigation system is increased by more than 30 tons. The model thus confirms that allocation by purchased shares results in a considerably more efficient use of both the irrigation water and the land in the hydraulic command area.

7.8 Comparative Analysis - Equity

The two principles of allocation not only affect the efficiency of resource use in different ways, they also have different implications for the equity of allocation of irrigation services. Typically, when equity of irrigation is examined, it is the equity of the distribution of benefits and costs within an irrigation system that is considered. Are the farmers whose land is in the tail of the system receiving their prescribed share of the water, or are the head-end farmers benefiting disproportionately? Are the benefits received and costs borne by different farmers proportionate, or is the ratio of benefits to costs different for different farmers? An irrigation system is said to be equitable if the head- and tail-end fields are served equally and the costs and benefits are proportionate for all farmers.

On these counts, the irrigation systems in Argali and Chherlung would be judged similarly equitable. The analysis of distribution in both locations has shown that the distribution of water has been equally satisfactory to fields in the head and tail. No systematic difference in stress-day counts between head and tail farmers or in the measured crop yields was observed. Since resources are mobilized on the basis of water allocation in both places, the criterion of proportionality of benefits and costs is met. The one slightly inequitable feature of resource mobilization (again in both locations) is the requirement that all member households send one laborer, irrespective of the amount of their water allocation, when emergency maintenance needs to be done. But, on the whole, the irrigation systems in Chherlung and Argali exhibit a high degree of equity internally under conventional measures of equity.

An aspect of equity that is not usually considered is the means of access to benefits from an irrigation system. In an essentially agricultural economy where irrigation is the primary factor affecting the productivity of land and labor resources, the ease of accessability to irrigation and the degree to which benefits of irrigation are widely distributed is an important measure of the equity of the institution of water allocation. The evidence supports the conclusion that allocation by purchased shares provides more equitable access to the irrigation water than does allocation in proportion to area irrigated. As mentioned above, the Thulo Kulo system in Chherlung has been rapidly expanded through sales of shares to the point where most of the hydraulic command area has been converted to khet on which monsoon rice is irrigated. In contrast, the area irrigated during the monsoon season in the Raj Kulo system in Argali has been restricted to less than half of the command area. Even though the water supply has been substantially increased, the irrigated area has remained largely unchanged because of the principle of allocation which ties the water rights to specific fields.

To acquire access to irrigation for rice in Argali, persons without land that has an allocation of water must purchase expensive khet fields that have been allocated water. In 1982, land of this type was sold for Rs. 20,000 per ropani, i.e., nearly Rs. 400,000 per hectare.[15] For a poor person (and people without irrigated land are almost certainly poor) this is hardly possible. In contrast, a person in Chherlung who owns some bari in the command area of one of the systems needs only to purchase a fraction of a share in the system; terrace, level, and bund some of his land; and begin irrigating a rice crop. Much less of a cash outlay is required to gain access to irrigation for the monsoon rice crop.

In the Hindu socio-cultural milieu of rural Nepal, persons who are of low-caste origin are nearly always poor. A test of which allocation principle provides more equitable access to irrigation would be to compare the percentage of low-caste members of the irrigation organizations in the two locations. Of the approximately 300 households which comprise the membership of the four irrigation organizations in Argali, only one is a low-caste household. This is a Damai[16] household, and the man had worked as a tailor in India for a number of years and saved enough to purchase a small plot of land with a water allocation. In contrast, the Thulo Kulo organization

---

[15] One hectare equals 19.66 ropanis. The exchange rate in 1982 was US $1.00 = Rs. 13.1, making the price of khet in Argali about $ 30,000 per hectare.

[16] Damais are considered untouchable by the high-caste Hindus and traditionally work as tailors.

in Chherlung has 20 low-caste households[17] out of a membership of 105 households. Most of these have joined since the number of shares in the system was expanded from 50 to 60 in 1978. Had the water allocation, as in Argali, been tied to the land which was already irrigated, preventing the expansion to the area where they own land, these poorer members of the community would not have had access to water to irrigate a rice crop. Thus, the evidence suggests that, as hypothesized, there is more equitable access to irrigation in systems which allocate water by purchased shares than in those which allocate it in proportion to area irrigated and bind the water rights to the land.

7.9 Origin of the Water Allocation Principle

An interesting question is why these two communities, located only a two-hour walk apart, developed such different principles of water allocation. It is the role of social scientists to try to understand why certain social institutions develop instead of others (Schotter, 1981). Most likely the differences, at least in part, are a result of the dissimilar ways in which the initial property-creating activity took place (Coward, 1983). Since all of the irrigation systems in Argali are more than a century old, no living residents have memory of their construction. The oral history of the Kanchi Kulo system, as recounted by one of the oldest residents with a reputation for

---

[17]Most of these are Majhis living in the tail of the system. They are also referred to locally as "boatees" ostensibly because they have traditionally operated the small dugouts which served to ferry people across the Kali Gandaki River at a number of places. I initially questioned this interpretation because "boat" is an English word but was assured by a number of people that this was true. With the construction of a number of bridges across the Kali Gandaki, they have had to rely more on agriculture for their livelihood. While ritually the Majhis are not as low in the Hindu hierarchy as the occupational castes, they certainly are a low socioeconomic class and are considered so by their high-caste Brahmin and Chhetri, as well as Magar, neighbors.

being the most knowledgeable concerning historical matters, is probably representative of the way in which a number of the irrigation systems in the hills were originally developed. The land which is the command area of the Kanchi Kulo system, as well as that above the canal which is now occupied by the hamlet of Phasran, was given as a birta grant to a man named Pandey by the Sen rajah of the kingdom of Palpa.[18] Birta were land grants made by the state to individuals and were usually, but not always, tax-free and inheritable (Regmi, 1978).[19] When the nation of Nepal was consolidated under the Shah dynasty in the late 18th century, the Pandey-birta was recognized by the new government and a lal mohor, or official government certificate, to that effect was issued to the descendants of the original recipient of the grant. Holders of birta grants had the authority to mobilize corvee labor from their tenants for various purposes, including the construction of irrigation systems (Regmi, 1972).[20] Thus, they had the capacity to mobilize resources, primarily labor, to construct an irrigation system, whereas the ordinary individual farmer could not have. The task of organizing the construction of an irrigation system would have been logistically easier for an individual with the status and authority of a holder of a birta grant than for a group of small farmers. Another advantage that

---

[18]Most of the present members of the Kanchi Kulo organization have the name Pandey and claim to be descendants of the Pandey to whom the original birta grant was given.

[19]Birta grants were usually given because of some service provided by the individual to the state. "Rewards for military service were generally given in the form of Birta grants" (Regmi, 1978:22).

[20]The Nepali word that Regmi uses for this forced labor is jhara. Interestingly enough, this same term is used by irrigation organizations in Argali and Chherlung for maintenance work that the members do on the system. In Argali jhara refers to emergency maintenance, while in Chherlung it is used for ordinary maintenance and the term for emergency maintenance is maha jhara. These terms must harken back to the days when tenents were forced to provide free labor to construct and maintain irrigation systems.

the holder of a land grant had was that it was the land most suitable for irrigation that was most likely given out as birta grants.

After an irrigation system was constructed under the authority of the birta holder, the water would have been allocated to the land of the birta grant only. Water may have been reallocated within the boundaries of the birta to adjust for differences in soil type and seepage and percolation, but it likely would not have been allocated to land outside of the birta.[21] Even though birta grants have been abolished[22] and the land is now registered in the name of individual farmers, the previously established allocation of water to the land of the birta grant essentially remains. According to the oral tradition, the Maili and Saili Kulo system command areas also occupy land that was granted as birta at one time.

The development of the Chherlung systems was different, as has been recounted earlier. It was not done under the authority of one person. Twenty-seven households collaborated in the construction of the canal for the Thulo Kulo system, and these were not all relatives. There was not a respected family patriarch whose authority to allocate the water would have been accepted by all. There was no specific, designated area like that of a birta grant to which the water could have logically been allocated. Also, two local residents financed the majority of the Rs. 5,000 construction contract, and they were interested in allocating water in such a way so as to recover some of their investment. Therefore, despite the fact that the four systems

[21]This type of reallocation within the boundaries of the birta could explain why there is some variation in the number of muris of water per hectare in the head end of the Kanchi Kulo system. It may also relate to the ambiguity of the exact meaning of the term muri as it referred to land area at the time the land was measured and registered for taxation. There might also have been errors in measurement of the land areas.

[22]In 1959 under the Nepali Congress Government, the Birta Abolition Act was passed (Regmi, 1978).

in nearby Argali and a small spring-fed system in Chherlung allocated water in proportion to area irrigated and tied the water rights to specific land, the Thulo Kulo organization chose to allocate water on the basis of how much individuals had invested in the construction of the system and to allow water rights to be transferred by sale independent of land transactions.

Allocation of water in proportion to area irrigated is a much more common practice in the farmer-managed systems in the hills of Nepal than allocation by purchased shares. Although allocation by purchased shares was reported to be the principle in several other locations in western Nepal, it was actually observed in only one other system in which a rapid appraisal was conducted. This was in the village of Asliwa in Gulmi District. The process of irrigation development in Asliwa was much like that in Chherlung. One individual landholder made the major investment for the construction of the canal. Due to delays for both financial and technical reasons, completion of the canal took 15 years. Water first flowed in the canal about four years after the Thulo Kulo in Chherlung began operating. Upon completion, water was allocated by sale of shares, and the primary investor recovered some of his investment. Since Chherlung and Asliwa are approximately a day's walk apart, it is possible that Asliwa was influenced by Chherlung's experience in allocating water.

7.10 Change in the Principle of Water Allocation

The theory of induced institutional innovation or the neo-institutional approach to economics holds that "economic agents pursuing their own selfish ends evolve institutions as a means to satisfy them" (Schotter, 1981:5). In other words, optimizing individuals in the pursuit of utility maximization develop institutional arrangements that will enable them to most efficiently achieve their objectives. In an economic environment such as rural Nepal where the rising demand for food is increasing the value of irrigation water, this theory would predict the evolution of property rights institutions that would allocate water more efficiently. There is some evidence that farmers in Argali may be moving towards adopting a practice of allocating water through the sale of shares. Several years ago, a plot with a water allocation in the Raj Kulo system was going to be taken out of agricultural production. The owner wanted to build a shop in the growing Argali bazaar on this land. It was arranged that the water allocation of this plot be turned over to the local school which then solicited bids for the water rights. Three bids were received, and the water right was transferred to a field of the person submitting the highest. The income went towards the school's budget.

The Raj Kulo system was improved in 1982 when the Department of Irrigation, Hydrology, and Meteorology implemented a rehabilitation project on the main canal. This involved installing hume pipe in much of the canal to protect it from rocks and earth falling from above and lining other sections.[23] There is general agreement that the supply in the Raj Kulo system is now sufficient in volume and reliability that the area irrigated could be safely expanded. As was already reported, at least some of the farmers believe that there is enough water to irrigate the entire command area during the monsoon rice season by using rotational distribution. In September 1982, the managing committee of the local high school sent a letter to the Raj Kulo irrigation organization requesting that 200 <u>muri</u> of water be sold from the system with the proceeds going to the school as an endowment to provide the school with a steady source of income for its annual

[23] The impetus for the rehabilitation project was the damage done to the canal when a road was being constructed above it, causing rock and dirt to fall down into the canal.

budget. The request was precipitated by information that the government was reducing its grant to the school's operating budget by 50 percent. It was not as if the school made the request without some notion as to the irrigation organization's likely receptiveness. Most of the members of the school committee were also influential members of the irrigation organization.

After a meeting of the Raj Kulo organization, at which the request and some of the mechanics of expanding the area were intensely discussed, a decision was made to sell 210 muri and 11 pathi of water.[24] This amount of water represented approximately 10 percent of the total supply. A committee was appointed to work out the details of the sale of water. The price of a muri of water was set at Rs. 2,000, and applications to purchase water rights were solicited. Requests for a total of 513 muri were received.[25] The committee decided who among the subscribers would be allowed to purchase water and set a date two weeks hence by which 25 percent of the purchase price had to be deposited in the bank account of the organization. The deposit receipt was to be turned over to the committee and a provisional certificate of water rights issued. Within six months the balance was to be paid, after which a permanent certificate would be issued and the persons taken in as new members in the organization. If the final 75

---

[24]The extra was added to the original request after a primary school also requested Rs. 30,000 assistance to improve its building. (There are 20 pathi in one muri.)

[25]This included a proposal by one individual to buy all of the water and cut a new canal above the existing Raj Kulo canal. The committee rejected the request for the following reasons: (1) he did not have sufficient land to be irrigated by this amount of water, (2) his proposed canal might damage the existing canal, and (3) he said if he could not use the water he would sell it to Phasran, a hamlet which at present is not part of the Raj Kulo organization. His statement that if he could not use all the water, he would sell it to Phasran is what resulted in unanimous rejection of his proposal by the committee. They did not want to see most of the water going to people who were not part of the communities which were already represented in the organization.

percent were not paid on time, the temporary certificate would be declared null and void, and the 25 percent would not be refunded.[26]

Ultimately, the sale of water rights was not consummated. There were two primary reasons for this failure. Cash is scarce, and hardly anyone was able to deposit the required 25 percent within two weeks. Many of the farmers thought that they would be allowed to acquire the water without paying the principal immediately if they just paid the annual interest on the cost of their water rights. The other reason is that the government decided not to reduce its contribution to the school's budget, obviating the crisis which had led to the decision to sell water rights. In 1984, a plan to sell water was again considered and approved. The impetus this time was a proposal to establish an agricultural college campus in Argali for which local funds were required. Again the sale did not go through because the government did not approve the proposal for a campus in Argali.

The fact that proposals to sell water rights continue to be put forward suggests that it will eventually happen and that the area irrigated for monsoon rice will be expanded. In the beginning, allocation by sale will be done only by the organization as a whole as has been proposed. The constitution of the Raj Kulo organization, which was written and adopted in 1984, delimits the potential sale of water rights. It prohibits members from selling shares of their water rights on an individual basis. The organization as a whole can decide to sell water rights. If it does so, the constitution states that the proceeds of the sale are to be given to some social organization, such as a school, which will benefit residents of both village panchayats in which the system is located. Conversion to complete

---

[26]This information came from the minutes of the Raj Kulo organization and the special committee appointed to manage the water sale. The researchers also attended all of the meetings.

transferability of water separate from the land, as is practiced in Chherlung, will take some time if it is ever to be adopted. There are indications, however, that the organization is ready to move away from allocation in proportion to area irrigated with the water rights strictly appurtenant to the land towards some form of market allocation. This is what induced innovation theory would predict if there is a need for more efficiency and if, in fact, allocation of water by purchased shares is more efficient as has been argued here. There is certainly a need for achieving higher efficiency in the allocation of water as population pressure increases the demand for agricultural production from the limited land and water resources.

The fact that Argali and Chherlung are located so near to each other in practically identical physical and socioeconomic environments, but employ fundamentally different principles of water allocation, has enabled an interesting analysis of the efficiency and equity impacts of these principles through primarily a comparative case study method. Field observations and the linear programming analysis confirm the tenet of economic theory that transferability of property rights in water, independent of the land, is an important characteristic of an economically efficient principle of water allocation. The data also suggest that allocation by purchased shares provides more equitable access to the irrigation resource than allocation in proportion to area irrigated.

CHAPTER 8: SUMMARY AND IMPLICATIONS

The field research on which this dissertation is based had the broad aim of investigating and understanding the operation and performance of farmer-managed irrigation systems in the hills of Nepal. The three more specific objectives of the dissertation were to:

1. Describe the different irrigation management organizations observed and the ways in which they carry out irrigation management activities.

2. Investigate the management of irrigation systems under differing water supply conditions to analyze (a) the relationship between water supply and the intensity of irrigation system management, and (b) the impact of water supply on the structure of the irrigation organizations.

3. Analyze the impact of different water allocation principles, e.g., water allocated in proportion to the area irrigated and water allocated by purchased shares, on the efficiency and equity of use of irrigation resources.

In this chapter, the main findings concerning these three objectives will first be summarized. This will be followed by a discussion of some of the implications that can be drawn from the research for irrigation development, both in Nepal and more generally.

8.1 Summary of Findings

8.1.1 Farmer Irrigation Organizations

A total of eight irrigation systems in four different locations were studied over one-and-a-half years. An additional ten systems were examined more briefly through the use of rapid appraisal techniques. In general, the farmer-managed irrigation systems were found to be well organized and effectively operated. Where the water supply was adequate, extremely intensive agricultural production was made possible by the irrigation systems. Three crops a year, including monsoon rice, winter wheat, and pre-monsoon maize or rice, were grown in three of the primary research sites as well as several of the rapid appraisal sites, and total yield rates for the three crops combined ranged from 7.5 to 8.4 tons/ha per year.

A surprising finding was that some of the systems irrigated more land in the winter and spring, when the water supply was at a relatively low ebb, than during the monsoon season when the supply peaked. In several of the systems studied, wheat and maize, which require much less water than flooded rice, were grown with irrigation on upland fields (bari). The total annual yield from these two crops combined approached 7 tons/ha in the one site where sample crop cuts of upland crops were taken. Clearly, the development and management of irrigation by farmers has been and continues to be a crucial factor in the adjustment by many communities in the hill region to the rapidly growing population and increasing demand for food.

In nearly all of the systems which were studied intensively, the water was distributed quite effectively and equitably. In most but not all of them, each field's allocation of water, as a proportion of the total flow in the system, was explicitly defined and known, and our measurement of the proportion of the total flow distributed to various parts of the system revealed that distribution matched the allocation with remarkable precision. The use of proportioning weirs (saachos) and rotational distribution made possible this accurate distribution of the water. Organizations adapted their method of distribution to supply conditions, employing methods which allowed for more precise control over the water when the supply was lower relative to demand.

Where necessary, the irrigation organizations were found to effectively mobilize substantial amounts of resources, both labor and cash, to maintain the diversion structures and conveyance canals and to make improvements to the system. Some of the systems had received one-time or occasional assistance from various agencies of the government, but had managed to retain their autonomy.

8.1.2 Management Intensity and Organizational Structure

The dissertation has examined the intensity of management in farmer-managed irrigation systems in the hills of Nepal and, in particular, how that management relates to the supply of water relative to the amount of irrigable land. In Chapter 1, it was shown that irrigation management consists of three sets of activities which deal directly with (1) the water, (2) the physical works which control the water, and (3) the organization that controls farmer behavior and the physical system, and, hence, the water. An increase in management intensity implies that management is being done in response to more information from the system's environment. There is an emphasis on response and adaptation to feedback rather than preset plans of operation. Management intensity is increased to gain more control over the water so that it can be used more efficiently and/or equitably.

Increasing the management intensity usually means the expenditure of more resources of one kind or another. Quantifying the increase in the intensity of each of the management activities is not always possible. The quantitative analysis here has dealt primarily with (1) management of distribution and the resources needed for its intensification, and (2) resource mobilization for maintenance of the system to acquire water. The level of organizational structure and complexity was analyzed and can be viewed as an overall measure of management intensity. One must, however, be careful because management can be informal as well as formal. A lack of formal organizational structure does not necessarily indicate that the degree of management intensity is low.

An initial hypothesis of this research was that both the intensity of management and the level of organizational structure would be inversely correlated with the relative amount of water supply. It was assumed that more intensive management and a more highly structured organization would be needed to manage efficiently a scarce supply of water compared to an abundant one. The higher marginal value product of water where it is less plentiful, relative to the amount of land that could be irrigated, would render more profitable a higher level of investment in the management of the water. The social control needed to manage water more efficiently would result in the development of more highly structured organizations in locations where the water supply is relatively scarce.

Analysis of the water management practices bore out the hypothesis that more intensive management would be practiced when the supply was relatively more scarce. For irrigating rice, distribution by continuous flow was the overwhelmingly preferred method of distribution, apparently because of its lesser labor requirement and the surety it provides that the crop will not suffer from yield-reducing moisture stress. In all locations this was the distribution method practiced if the water supply was sufficient. Rotational distribution for rice was only done when the supply was not adequate for continuous-flow distribution. The evidence is somewhat ambiguous as to which method of distribution actually requires more total labor over the season, but the amount of labor observed going directly into distribution of the water was higher for rotational distribution than for continuous-flow.

The linear programming model developed to represent the Kanchi Kulo irrigation system in Argali confirmed rotational distribution to be the optimal method if the water supply were reduced. Sensitivity analysis for variations in the water supply permitted the tracing out of an isoquant showing the trade-off between water and management labor. The shadow price, or marginal value product, of water was quite low as long as a reduction in the supply only meant that more labor would have to go into managing the water. However, at the point where further reduction of water would result in less area being irrigated, the shadow price increased significantly.

Data from the Kanchi Kulo system showed that farmers whose fields were in that part of the system which was able to practice continuous-flow distribution throughout the entire season did significantly more intensive land preparation than those who had to distribute a lesser amount of water by rotation. For that system, the linear programming model selected rotational distribution as the optimal management practice even when there was plenty of water. Two explanations for this were tested. The one was that the labor for rotational distribution is considered more of a bother or aggravation (dukha) than other kinds of labor because it requires a farmer to go out to irrigate at night and to be in one's fields alone. According to the model, the labor for rotational distribution would have to be costed at a figure six times that of the ordinary wage rate for continuous-flow to be the optimal method of distribution. The farmers do consider rotational distribution a bother, particularly when their turn falls at night, but it is unlikely that they would consider it to be six times worse than labor for land preparation.

A more likely reason for the farmers' strong preference for continuous-flow distribution is that, over the long term, average yields from fields to which water is distributed by rotation would be somewhat less than from those served by continuous-flow. Although there was no difference in 1982 when yields were measured, in years when the water supply is scarcer there might be significantly lower yields, as a result of moisture stress, in the fields under rotation. The model was used to determine how much the yield reduction under rotation would have to be for continuous-flow to be optimal. A reduction of 0.2 tons/ha (i.e., from 3.5 to 3.3) resulted in continuous-flow being the optimal method of distribution.

Analysis of the structure of the irrigation organizations and the determinants of the level of organization, however, did not reveal the degree of structure to be related to the level of water supply relative to the area that could be irrigated. The amount of labor required to maintain the system and the consequent need to mobilize resources from the members of the organization for this maintenance appear to be the primary determinants of the structure of the organizations of the farmer-managed irrigation systems studied. In the Nepal hill region, where the environment is characterized by a monsoon climate and steep unstable hillsides, irrigation organizations are designed more for water acquisition than for distribution of the water. The key ongoing activities for water acquisition are system maintenance and mobilization of the resources to do the maintenance. Very intensive management was employed in maintaining the system for acquisition of water. Systems requiring a greater amount of resource mobilization for maintenance were found to have a higher level of organizational structure than those which did not need as much maintenance.

The eight organizations studied were ranked according to their observed level of organizational structure. The Spearman rank correlation coefficient was then used to test which variables resulted in rankings most closely matching the observed ranking. The predictor with the highest correlation coefficient was "total annual maintenance labor." "Maintenance labor per member" and "maintenance labor per hectare" were the next best predictors of level of organizational structure. The two variables with the lowest correlation coefficients were the water supply variables, i.e., supply relative to the hydraulic command area (GRWS) and supply relative to the area actually irrigated (NRWS).

Irrigation systems which required a high level of maintenance labor to acquire the water also performed better in providing each farmer the proportion of the supply which he had been allotted. Farmers in systems requiring much labor for maintenance were well aware of the amount of their water allocation, and the distribution system was designed to deliver it to them. The oft-cited head-tail problem, with the farmers at the head taking more than their share of the water, was not observed in these systems. Head-end farmers had to rely on the participation of tail-end farmers in the maintenance activity to keep the supply flowing and for contributing to improvements in the diversion structure and canal to increase the supply. Without receiving a fair share of the water, tail-end farmers would not be willing to contribute the substantial amounts of resources needed to acquire and maintain the water supply. The high maintenance requirements created an interdependence between head and tail farmers which was, at least in part, responsible for the more equitable distribution of the water in these systems. The only system in which the observed number of stress days was significantly higher and the level of yields significantly lower in the tail than in the head was the Tallo Kulo system in Thambesi, the system which required by far the lowest annual expenditure of resources for maintenance.

8.1.3 Principle of Water Allocation

The traditional convention of water rights and the principles by which water is allocated within an irrigation system were found to be very important factors in the efficiency and equity of irrigation resource use. The doctrine of prior appropriation of rights to water from the irrigation source provides security to the developers of an irrigation system that they will reap the benefits of their investment. This is necessary to encourage investment of the relatively large amount of resources needed for digging a canal that may be long and have to pass along the face of cliffs and unstable, landslide-prone slopes. If irrigators are to be willing to contribute the substantial amounts of labor and cash required to maintain the structures, they also need some assurance that they will receive their allotted water.

However, if there is no flexibility in the principle of water allocation to allow for water to be used beyond the area that was originally allocated the rights, this can result in a socially inefficient restriction of access to the water. The common principle of allocating water to fields in proportion to the percentage of the total fixed irrigated area that they occupy does not provide a mechanism for expanding the irrigated area, even if the system is improved so that more water can be delivered. The Raj Kulo system in Argali is a good example of a system in which the water supply has been significantly increased but the area irrigated has remained relatively fixed, largely because water is allocated in proportion to the area irrigated within previously specified boundaries.

Allocating water according to purchased shares provides individual farmers an incentive to allow the area to expand. As the supply is increased due to improvements in the physical system, the amount of water represented by a share also increases. A farmer (or group of farmers) who then has more water than he feels is sufficient can recover some of his investment by selling shares. By selling shares he also reduces the amount of labor and cash he must contribute annually, as this is assessed in proportion to members' shareholdings. Sale of shares also provides a mechanism by which the area irrigated will continually expand, as it has in Chherlung. More people are able to acquire access to irrigation under this principle of water allocation.

Analysis with the linear programming model estimated the social opportunity cost of restricting access to irrigation water to the land area that has been irrigated by the Kanchi Kulo system for many years. When the model was adapted to allow for selling of water shares as in Chherlung, the area irrigated was increased by nearly 80 percent and the value of the objective function by a similar amount. This potential increase in the objective function represents the social opportunity cost of restricting transfer of water rights and, thus, the access to irrigation.

Analysis of the institution of water rights and the principle of water allocation shows us how some organizations might adapt to an increasing demand for food production and, therefore, for access to irrigation. The fact that the Raj Kulo organization in Argali has in fact considered selling water shares is an indication that under the pressure of increasing demand for food, the organization may change to the more efficient means of allocation by purchased shares. By doing so, the area that is irrigated during the monsoon season (and therefore triple-cropped) would, according to Argali farmers, probably nearly double. More households would be able to grow their own rice. Also the fields converted to <u>khet</u> would have a higher priority for irrigation in the winter wheat and pre-monsoon maize seasons than they did as bari, resulting in more security of production of these crops.

8.1.4 Conclusion

In summary, the irrigation systems in the hills of Nepal should be viewed as dynamic, changing over time and varying across locations in response to resource limitations. As population has grown, the systems have responded to the increased demand for food by increasing the intensity of both agricultural production and irrigation managment. Our analysis across sites allows us to speculate on the next step in development of a given site. Chherlung, for example, seems to have reached the limits of its production capacity with existing technology. Argali, on the other hand, could probably expand production, if it were to adopt the principle of water allocation based on ownership and sale of water shares as practiced in Chherlung. Thambesi seems poised to follow in the steps of Chherlung and Argali and intensify crop production in the non-monsoon seasons. A clearer understanding of the dynamic process of adaptation and an identification of each specific site's stage of development could make it possible for external agencies to assist irrigation systems in the process of transistion.

8.2 Implications

Implications that can be drawn from this research are more relevant to irrigation development and management in the hills of Nepal and in other hill environments than to large, bureaucratically-managed systems on the plains. The irrigation systems that were studied in depth are small, ranging from about 10 to 50 hectares in area with between 28 to 158 member farmers. Both the size and the specific nature of the environment in which the systems exist place some limitation on the generalizability of the implications that can be drawn from this study. The learning gained from the analysis of these systems can assist, however, in understanding some of the management issues and problems in irrigation systems in other places.

8.2.1 Effectiveness of Farmer Organizations for Irrigation Management

Government planners have realized that irrigation development is essential for the intensification of agricultural production in Nepal and that this can be accomplished only through the participation of the irrigators who are to benefit. This study has shown how effective farmer organizations can be in managing irrigation systems to achieve extremely intensive agricultural production, e.g., in Argali and Chherlung, three irrigated crops per year are grown on lowland (*khet*) and two irrigated crops, on irrigated upland (*bari*). Without the intimate involvement of the irrigators, the achievement of such intensive agricultural production would likely not be possible.

8.2.2 Resource Mobilization for Water Acquisition

There are costs involved in operating and maintaining an *organization*, and farmers will only organize to the extent that it is in their interest to do so. The organizational requirements of mobilizing large amounts of resources to maintain irrigation systems lead to highly structured organizations in systems which require much maintenance. Where the organizational needs are less, there is no point in developing a highly structured organization. Intensive management of *distribution* of a scarce water supply does not appear to require the same degree of organizational complexity as intensive management of *acquisition*, i.e., mobilization of resources for maintenance of the system. Also, not all farmers have the same incentives to intensify management of distribution, whereas they do for acquisition of water. Head-end farmers are in an advantageous position to take water whenever they want it and do not reap the same benefits from intensification of distribution that tail-enders, who will receive adequate water only if management of distribution is intensified, do. However, if the water supply can be acquired only by doing considerable maintenance to the system, all farmers have an incentive to participate and to see that the other members also do. Developing effective water-user organizations in irrigation systems where the farmers do not have to do anything to acquire the water has often proved to be difficult, and this is likely one of the reasons.

The fact that the organizations of systems which require a large amount of labor for maintenance are stronger and more effective in distributing the water according to the recognized allocation has an extremely important implication. The interdependence of the head and tail farmers, i.e., the fact that the effort of all of them is needed in water acquisition, mitigates the traditional head-tail problem. One could question whether interventions by government agencies should be made which will result primarily in a reduction of the amount of maintenance required to be done by water users. Such assistance might lead to a weakening of the organization. If the head-end farmers are no longer dependent on the participation of the tail-enders in the maintenance of the system to keep the water flowing, the result could be less equitable and efficient distribution of the water.

In new systems being constructed, consideration should be given to building in regular investments that the organization of farmers will have to make <u>collectively</u> to acquire water. If the tail-enders have helped acquire the water, there is more pressure on the head-end farmers to allow the water to go to the tail according to the scheme of allocation. This may best be done in systems which are being developed by a government agency by giving the organization of farmers more responsibility for the operation and maintenance of the main system. They would then be collectively responsible to raise resources to operate and maintain the system, resulting in a degree of interdependency.

8.2.3 Water Rights and Their Allocation

One of the most important findings is that property rights in water are normally well defined in farmer-managed irrigation systems. This is particularly true of systems that need to mobilize much labor for system maintenance, with the allocation of property rights serving as the accounting unit for mobilizing resources as well as the determinant of water distribution in the system. Property rights were found to be less well defined in systems not needing to mobilize many resources for water acquisition. If a government agency is going to assist a farmer-managed system with an objective of increasing production, it is very important that it first gain an understanding of the existing property rights. These rights are well established and accepted in the area, and any intervention that does not recognize and respect them is likely to meet with resistance.

The principle of water allocation was found to have a significant impact on the efficiency and equity of irrigation resource use, i.e., on the extent to which the area that is irrigated is extended to the socially efficient size and the way in which people without an original water allocation can gain access to irrigation. In irrigation development, attention should thus be paid to the principle of allocation. If water is a scarce resource, an allocation principle which contains incentives for efficient use of water as well as a mechanism allowing for expansion of the area irrigated should be implemented. The allocation principle observed that had these characteristics was allocation by purchased shares. In systems that are water constrained, i.e., where there is additional land that could be irrigated with an increase in supply, intervention to increase the supply will likely not lead to the desired expansion if allocation is in proportion to area irrigated. A change to allocation by purchased shares should be considered as a condition for providing the assistance.

8.2.4 Intensive Irrigation Management in Response to Population Pressure

Farmer-managed irrigation systems in the hills of Nepal are intensifying management in response to growing population pressure and an increasing demand for food. Both the organization for water acquisition and the nature of property rights in water affect the capacity to manage and utilize water more efficiently. Thus we find these relationships changing over time in locations where more intensive irrigation management will permit a higher production of food from a given area. The hill irrigation systems, while enabling an impressive intensification of agricultural production, do not seem to be capable of creating the agricultural surplus needed for development. Rather what appears to be happening in the areas studied is an agricultural involution similar to what Geertz (1963) described for Indonesia. The population and land-use statistics presented in Tables 3.14 and 3.15 suggest that the irrigation systems achieve a dynamic equilibrium which allows for the support of a larger population with intensification of irrigation management and agricultural production but not for the creation of surplus.

It cannot be assumed that factors which permit greater management intensity in the farmer-operated irrigation systems in the hills of Nepal will operate in the lowlands. For instance, the formation of effective water-user groups in large-scale systems on the plains where farmers do not have to collectively invest in the acquisition of the water may be difficult to accomplish. While the organizations in the hill systems proved to be most effective where they had to mobilize substantial amounts of resources for water acquisition, i.e., for maintenance to keep the water flowing, how to transfer this learning to large-scale, bureaucratically-managed systems on the plains is not obvious. The fact that in the lowlands farmers normally do not have to organize to provide labor input to acquire water weakens the dependency of the head-end farmers on the tail-enders and creates a typical head-tail problem which must be overcome by other means. In short, the need to intensify irrigation management in lowland systems will require a very different set of actions.

The farmer-managed irrigation systems in the hill region of Nepal have proved to be fruitful subjects of research for several reasons. While they are located relatively close to each other, they are also situated in somewhat different environments. The organizations represent a rich diversity because they respond in different ways to these different environmental conditions. Their relative smallness allows one, with less expenditure of resources, to gain a fuller comprehension of the manner in which a system is operated and of the effectiveness of the management than would be possible if the command area covered tens of thousands of hectares. Logical conclusions and implications can be drawn from the observations. While solutions to irrigation managment problems in other types of systems cannot be transferred directly from the farmer-managed hill systems of Nepal, learning derived from this study can help in understanding the dynamics of other systems.

Appendix A

THE PLACEMENT OF A SAACHO

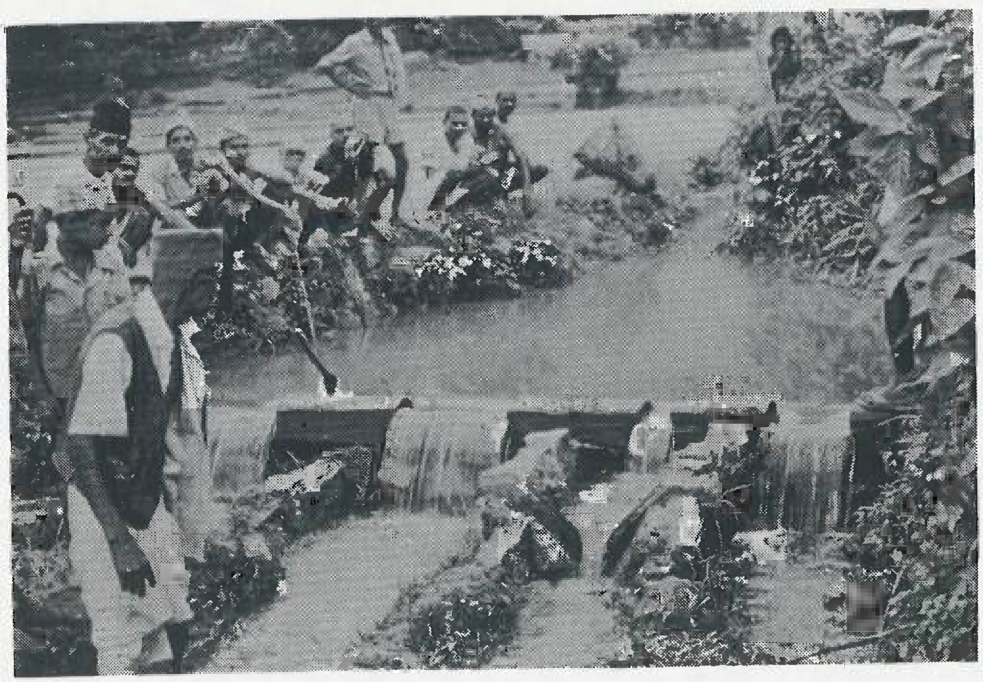

Figure A.1: Farmers checking the placement of a *saacho* installed to distribute the flow from the main canal into four secondary canals according to the water allocation of each.

Appendix B

ANNUAL MAINTENANCE LABOR
(man-days/year)

Table B.1 Argali Raj Kulo Maintenance Labor

Year	Routine Maintenance	Emergency Maintenance	Total
1961	1120	681	1801
1966	1251	92	1343
1967	1120	690	1810
1968	1085	371	1456
1969	1120	825	1945
1970	1453	a	a
1971	1135	161	1296
1972	1003	159	1162
1973	1032	543	1575
1974	1287	205	1492
1975	1104	358	1462
1976	1203	294	1497
1979	1264	1378	2642
1980	1087	638	1725
1981	1322	985	2307
1982	1179	822	2001
1983	1271	599	1870
1984	926	449	1375
Average	1165	544	1694

[a]Missing

Table B.2 Argali Saili Kulo Maintenance Labor

Year	Routine Maintenance	Emergency Maintenance	Total
1977	449	a	a
1978	374	657	1031
1979	454	732	1186
1980	391	685	1076
Average	417	691	1098

[a]Missing

Table B.3 Argali Maili Kulo Maintenance Labor

Year	Routine Maintenance	Emergency Maintenance	Total
1971	325	272	597
1973	290	132	422
1974	481	306	787
1975	451	554	1005
1976	405	234	639
1977	487	328	815
1978	406	169	575
1979	332	238	570
1980	449	194	643
1981	673	444	1117
1982	593	230	823
Average	445	282	727

Table B.4 Argali Kanchi Kulo Maintenance Labor

Year	Routine Maintenance	Emergency Maintenance	Total
1978	307	183	490
1979	281	150	431
1980	302	285	587
1981	246	248	494
1982	312	226	538
Average	290	218	508

Table B.5 Chherlung Thulo Kulo Maintenance Labor

Year	Total
1981	1811
1983	3541
1984	1362
Average	2238

Table B.6 Chherlung Tallo Kulo Maintenance Labor

Year	Total
1978	1350
1979	2005
1980	1950
1981	2740
1982	1700
1983	1400
1984	1305
Average	1779

Appendix C

CONSTITUTION OF RAJ KULO IRRIGATION ORGANIZATION, KHEHA-ARGALI

In about 1604 Bikram Sambat (1547 A.D.) Palpa's King Mani Makunda Sen established the temple of God Shree Rishikesh in Ridi, Palpa. In order to establish an endowment for the daily expenditure for the worship of the diety and for the priests, the king, with the help of the people, decided to develop paddy land (khet). It was developed at what is now the large terrace in Rabidas, which was equivalent in area to produce 40 muri of paddy. It was further decided to allocate 7 pathis of paddy and 7 pathis of wheat out of the produce to the priests. To irrigate this land, a canal was constructed, diverting water from the Kurung Khola at Jorte. The canal at that time was not in as good condition as it is today, and the amount of water flowing through it was much less.

Since there was sufficient land in Argali Village Panchayat which could be developed into khet, after a few years people from Rabidas, Tallo Saya, Mathillo Saya, Chaar Saya, Tin Saya, Gham Pani, and Khutilam converted their land into khet. Now the people needed more water from the canal to irrigate their land, so the farmers started repairing the Raj Kulo to deliver more water for their crops. They tried to bring water from Laghuwa Khola by cutting the canal from above Khugurdi, but that was not successful. Due to the perseverance and effort of the farmers, the canal was improved and there was more water for irrigation.

The Rana Prime Minister Shree Juddha Shumshere settled in Argali after his retirement. He helped financially to improve the canal in 2002

Bikram Sambat (1945 A.D.). In the fiscal year 2038-39 (1982), the government of Nepal repaired the canal. The canal was reconstructed with cement pipe and lining from the source up to Khutilam. After that, people started getting water more easily.

The sources of the Raj Kulo are as follows: (1) the Kurung Khola, and (2) the waterfall of the Laghuwa Khola. The water from the canal can irrigate 2000 maato muris of land (old method of measurement), and according to the present method, this canal can irrigate 46 hectares of khet land and 50 hectares of pakho bari. The length of the canal from Jorte to the Saacho is 3 kilometers.

Distribution of water: On the basis of the total water from the canal irrigating 2000 muri of land,

1. From Khugurdi towards the intake, consisting of Ripaha and Kusunde, it was decided to provide 1 laborer equivalent to 40 pani muri.
2. From Khugurdi to Khutilam 1 laborer for 40 pani muri.
3. Four laborers for 120 maato muri.
4. As per the traditional rule that each side of the rest will provide equal number of laborers, 22 laborers will be provided from each side. Thus the total number of laborers amounts to 50.

Rules and regulations of the Raj Kulo.

1. For a distance of 100 yards upstream from the source of the Raj Kulo, no one shall be allowed to tap water for irrigation or for any other purpose whatsoever.
2. No water shall be wasted while irrigating khet in the vicinity of the source. If someone is found to be neligent in this regard, a proper fine will be imposed on him by the committee, if one exists, or by the concensus of the majority of the water users as the case may be.
3. The general meeting of this canal shall be held twice a year--on the first day of Jestha (mid-May) and the last day of Mangsir (mid-November). The decisions regarding the maintenance of the canal will be made in the meeting in Mangsir, and fines for the year are also collected then. The

Jestha meeting will be used for giving a detailed description of the the work done on the canal in the previous year and for presenting the account of the expenditures incurred and pending matters of the accounts to be settled.

4. Minors under the age of 14 and women shall not be allowed to work on the canal.

5. If there is only a minor child in the family, the organization does not require them to provide labor, but if cash is raised to improve the canal they have to pay according to their maato muri.

6. Widows and persons having no relatives have to contribute laborers.

7. Except in cases of emergency, work on the canal will be from 12 p.m. to 5 p.m.

8. The members are to be informed if there is work to be done on the canal. A peon shall be deputed to inform everyone.

9. Work will be carried out according to the instructions of the chairman, secretary, or members of the committee. Anyone who does not work according to the instructions or who is found to be negligent, shall be marked absent.

10. One man working for the whole day will be considered as a contribution of one laborer.

11. It is the responsibility of the secretary to keep the updated record of attendance. Should anyone demand his attendance record, the secretary must be able to produce his record and explain it.

12. If any member of the family of one of the members dies while work on the canal is in progress, then such persons who have to perform religious functions for a certain period of time shall be exempted from labor contributions during this period. One other person who will help such persons shall also be exempted from the labor contributions. The secretary must be notified who the concerned person is.

13. People working on the canal will be excused from work if there is some emergency or death in the family. They must inform the secretary as soon as possible.

14. The secretary will be responsible for keeping the accounts of income and expenditure of the organization and for looking after the tools and other property of the organization.

15. The details of income and expenditure are to be presented at the general meeting for approval by the members.

16. The secretary may keep up to Rs. 500 with him at any time. Amounts in excess of this are to be deposited in the bank or loaned to members of the organization.

17. The chairman and secretary will each be remunerated at the rate of two laborers for each day that they must report to work.

18. One person (pani jaachne)shall be employed to check the flow of water in the canal every day. He is also responsible to record whether the two men who are to patrol the canal have actually gone to work. He shall report to the secretary about the condition of the canal, and decisions regarding the necessity of maintenance shall be made by the secretary.

19. Two regular canal watchmen (pale), one from each side of the main saacho shall be appointed by the decision of the general meeting effective from the first of Jestha and will be paid on a daily basis.

20. The one who assigns the pale have to send them daily, turn by turn, and according to the need.

21. If the assigned pale does not go to work, the pani jaachne should send another person who will be paid one day's wage. The pale who failed to go will be fined one day's wage.

22. Irrigation water for monsoon rice will be applied according to one's share of labor contribution based on landholding.

23. No farmer is allowed to sell his share of water on an individual basis.

24. No one is allowed to adversely affect other people's land and crops while irrigating his own field.

25. Silt and debris removed from the field channels is to be deposited on the downhill side of the channel.

26. The labor wage rate will be fixed by the general meeting in accordance with the current local rate.

27. Water for monsoon rice shall be distributed by saacho in individual fields in proportion to the labor contributed based on the size of landholding.

28. Excess water will be drained in the traditional way.

29. Emergency maintenance is not to be declared unless it is truly an emergency. Otherwise the canal should be operated under routine maintenance procedures.

30. Person interested in irrigating winter crops can do so by making necessary repairs to the canal on their own.

31. The first person to start work on the canal will have the right to use water first.

32. If someone's crop is adversely affected due to lack of irrigation water, it will be the responsibility of the secretary and the chairman to carry out an inspection and to arrange for distribution on a rotational basis.

33. The _bari_ will be irrigated during the day time and the _khet_ during the night in the case of winter irrigation. This will be under the supervision and the responsibility of the secretary. He will be remunerated the equivalent of one laborer for this duty.

34. The secretary will be responsible for the allocation of irrigation water in Khutilam and in the vicinity of the source for winter season irrigation.

35. In the case of winter season irrigation based on mutual agreement, water can be adjusted between Ranuwa and Rabidas in the case of necessity irrespective of the traditional 50-50 basis and irrespective of the number of members contributing labor from each side of the _saacho_.

36. The traditional system of water distribution using the wooden _saacho_ based on the measurement of fingers is considered unscientific, and, henceforth, it will be modernized and measurement will be based on inch, feet, or centimeters.

37. The _saachos_ in important places will be placed in due time in the case of monsoon season irrigation and water distributed accordingly. _Saachos_ in other field channels will be placed based on their importance, but once the crop is planted, it is the duty of everyone to place a _saacho_, according to one's share of water, at the head of his field.

38. If water is stolen from a _saacho_ on the main canal after the rice has been transplanted and before water is no longer required, the whole group of farmers under that _saacho_ will be fined at the following rates:

First time	Rs. 50 - Rs. 100
Second time	Rs. 200 - Rs. 300
Third time	Rs. 500

If later on it is proved that it was the work of one individual, the the whole amount of the fine shall be realized from him and deposited in the main account of the organization.

39. If someone is apprehended stealing water from a field channel, then a fine of Rs. 25 to Rs. 50 can be imposed. The fine, if collected, is to be used for future maintenance work of the field channel.

40. No fine shall be imposed if it is proved that the _saacho_ was altered by natural causes.

41. If the water in the canal is more than is needed, then a decision to sell the surplus water can be taken by a majority vote at a general meeting of all the members, and water can be regulated through the _saachos_ accordingly. The money thus raised shall be deposited in the account of social organizations benefitting both panchayats, such as schools.

42. If anyone is interested in operating any kind of industry using the water from the canal, he can do so, provided that it will have no harmful effects on the irrigation of crops. For this a reasonable amount of

money will be charged him, and it can be used for any social organization.

43. The canal organization will have its own account. If money collected for maintenance is not needed, the secretary can retain cash with him up to Rs. 500. The rest of the amount will be either deposited in the bank or loaned to some individuals to accrue interest as decided by the committee.

44. This Raj Kulo organization shall have a separate constitutional executive committee. Members of this committee will be elected by popular vote of the members. The term of the committee will be one year.

45. This committee for the canal operation can formulate rules in the case of a natural calamity when there is no possibility of a general meeting being held immediately. These rules must later be approved at a general meeting.

46. If the committee, secretary, or chairman are found to have been negligent or to have worked against the rules of the organization, the committee can be dissolved by a two-thirds vote of the members.

47. The organization shall have its own stamp.

48. This constitution shall be in effect after being ratified at a general meeting.

49. The rules set forth in the constitution can be amended by a decision at a general meeting.

50. From the main saacho toward the intake, the labor assessment will be one laborer for 30 pani muri, and below this it will be one laborer for 40 pani muri.

REFERENCES

Adams, Robert McC. 1974. "Historic Patterns of Mesopotamian Irrigation Agriculture." In: Theodore E. Downing and McGuire Gibson (eds.). Irrigation's Impact on Society. Tucson: The University of Arizona Press.

Anderson, Terry L. (ed.). 1983. Water Rights: Scarce Resource Allocation, Bureaucracy, and the Environment. Cambridge, Mass.: Ballinger Publishing Co.

Asian Development Bank. 1982. Nepal Agriculture Sector Strategy Study. Manila: Asian Development Bank.

Bajracharya, Deepak. 1982. Implications of Fuel and Food Needs for Deforestation: An Energy Study in a Hill Village Panchayat of Eastern Nepal. Unpublished Ph.D. dissertation. Sussex: Sussex University.

Barker, Randolph, E. Walter Coward Jr., Gilbert Levine, and Leslie E. Small. 1984. Irrigation Development in Asia: Past Trends and Future Directions. Cornell Studies in Irrigation, No. 1. Ithaca: Cornell University.

Bowen, Richard L. and Robert A. Young. 1984. "Economic Effects of Alternative Methods of Charging for Irrigation Water: A Case Study in Egypt." Paper presented at the Annual Meeting of the American Agricultural Economics Association, August 5-8, 1984. Ithaca, NY: Cornell University.

Central Bureau of Statistics. 1974. Population Census, 1971. Kathmandu: National Planning Commission Secretariat, His Majesty's Government of Nepal.

Central Bureau of Statistics. 1984. Population Census, 1981. Kathmandu: National Planning Commission Secretariat, His Majesty's Government of Nepal.

Chambers, Robert. 1980. "In Search of a Water Revolution: Questions for Managing Canal Irrigation in the 1980s." Sussex: Institute of Development Studies.

Cheung, S. 1974. "The Structure of a Contract and the Theory of a Non-Exclusive Resource." In: Eirik G. Furubotn and Svetozar Pejovich (eds.). The Economics of Property Rights. Cambridge, Mass.: Ballinger Publishing Co.

Ciriacy-Wantrup, S.V. 1955. "Some Economic Issues in Water Rights." Journal of Farm Economics. No. 37.

Ciriacy-Wantrup, S.V. 1964. "Concepts Used as Economic Criteria for a System of Water Rights." In: Stephen C. Smith and Emery N. Castle (eds.). Economics and Public Policy in Water Resources Development. Ames, Iowa: Iowa State University Press.

Ciriacy-Wantrup, S.V. and Richard C. Bishop. 1975. "'Common Property' as a Concept in Natural Resource Policy." Natural Resources Journal, Vol. 15 No. 4.

Commons, John R. 1934. Institutional Economics: Its Place in Political Economy. New York: The MacMillan Company.

Commons, John R. 1951. The Economics of Collective Action. New York: The MacMillan Company.

Coward, E. Walter (ed.). 1980. Irrigation and Agricultural Development in Asia. Ithaca: Cornell University Press.

Coward, E. Walter, Jr. 1983. "Property in Action: Alternatives for Irrigation Investment." Presented at Workshop on Water Management and Policy, Khon Kaen University, Khon Kaen, Thailand. September 1983.

Coward, E. Walter, Jr. 1985a. "State and Locality in Asian Irrigation Development: The Property Factor." In (forthcoming): Current Issues in and Approaches to Irrigation Water Management in Developing Countries. Boulder, Colorado: Westview Press.

Coward, E. Walter, Jr. 1985b. "Property, Persistence, and Participation: The State and Traditional Irrigation Systems." Paper prepared for the 1985 meeting of the Society for Economic Anthropology. Airle House, Warrenton, Virginia.

Demsetz, H. 1974. "Toward a Theory of Property Rights." In: Eirik G. Furubotn and Svetozar Pejovich (eds.). The Economics of Property Rights. Cambridge, Mass.: Ballinger Publishing Co.

Ditwiler, C. Dirck. 1975. "Water Problems and Property Rights--An Economic Perspective." Natural Resources Journal, Vol. 15 No. 4.

Doan, Peter, David Douglin and Norman Uphoff. 1984. "Local Institutional Development for Natural Resource Management." Special Series on

Local Institutional Development No. 2. Ithaca: Rural Development Committee, Cornell University.

Downing, Theodore E. 1974. "Irrigation and Moisture-Sensitive Periods: A Zapotec Case." In: Theodore E. Downing and McGuire Gibson (eds.). Irrigation's Impact on Society. Tucson: The University of Arizona Press.

Eckholm, Eric. 1978. Losing Ground. Boulder: Westview Press.

Eheart, J. Wayland and Randolph M. Lyon. 1983. "Alternative Structures for Water Rights Markets." Water Resources Research, Vol. 19 No. 4.

Furubotn, Eirik G. and Svetozar Pejovich. 1972. "Property Rights and Economic Theory: A Survey of Recent Literature." Journal of Economic Literature 10.

Furubotn, Eirik G. and Svetozar Pejovich. 1974. The Economics of Property Rights. Cambridge, Mass.: Ballinger Publishing Co.

Gardner, B. Delworth. 1981. "The Water Management Crunch: An Economic Perspective." In: Walter E. Jeske (ed.). Economics, Ethics, Ecology: Roots of Productive Conservation. Ankeny, Iowa: Soil Conservation Society of America.

Geertz, Clifford. 1963. Agricultural Involution. Berkeley: University of California Press.

Geertz, Clifford. 1980. "Organization of the Balinese Subak." In: E. Walter Coward (ed.). Irrigation and Agricultural Development in Asia: Perspectives from the Social Sciences. Ithaca: Cornell University Press.

Glick, Thomas F. 1970. Irrigation and Society in Medieval Valencia. Cambridge, Mass.: Belknap Press.

Hardin, Garrett. 1977. "The Tragedy of the Commons." In: Garret Hardin and J. Baden (eds.). Managing the Commons. San Francisco: W.H. Freeman & Co.

Hexem, R.W. and Earl Heady. 1978. Water Production Functions of Irrigated Agriculture. Ames, Iowa: Iowa State University Press.

Hogg, H. and G.H. Vieth. 1977. "Method for Evaluating Irrigation Projects." Journal of the Irrigation and Drainage Division, American Society of Civil Engineers. Vol. 103, No. IR1.

Hollowell, Peter G. (ed.). 1982. Property and Social Relations. London: Heinemann.

Huffman, Roy E. 1953. Irrigation Development and Public Water Policy. New York: The Ronald Press Company.

Huszar, Paul C. and Melvin B. Sabey. 1978. "Improving Irrigation Return Flow Quality with a Water Rental Market." Water Resources Bulletin, Vol. 14 No. 4.

Jeske, Walter E. 1981. Economics, Ethics, Ecology: Roots of Productive Conservation. Ankeny, Iowa: Soil Conservation Society of America.

Kathpalia, G.N. 1984. "The Nong Wai Irrigation Project, Thailand." In: Irrigation Management Network Paper 10c. London: Agricultural Administration Unit, Overseas Development Institute.

Kelly, William W. 1983. Irrigation Management in Japan: A Critical Review of Japanese Social Science Research. Ithaca: Rural Development Committee, Cornell University.

Landon, Richard P. 1979. "The Gift of Land: Irrigation and Social Structure in a Toba Batak Village." Unpublished Ph.D. dissertation. Berkely: University of California.

Leach, Edmund R. 1959. "Hydraulic Society in Ceylon." Past and Present, No. 15.

Leach, E.R. 1961. Pul Eliya a Village in Ceylon: A Study of Land Tenure and Kinship. Cambridge: University Press.

Levine, Gilbert. 1977. "Management Components in Irrigation System Design and Operation," in Agricultural Administration 4, No. 1.

Levine, Gilbert. 1979a. "Hardware and Software: An Engineering Perspective on the Mix for Irrigation Management." In: Report on a Planning Workshop on Irrigtion Water Management. Los Banos, Philippines: International Rice Research Institute.

Levine, Gilbert. 1979b. "Water Use and Water Management - Tradeoff Implications for Water Efficiency." Presented at IFPRI-IRRI-IFDC Symposium on Rice Policy. Los Banos, The Philippines.

Levine, Gilbert. 1981. "Perspectives on Integrating Findings from Research on Irrigation Systems in Southeast Asia." Presented at Agricultural Development Council Workshop on Investment Decisions to Further Develop and Make Use of Southeast Asia's Irrigation Resources. Bangkok: Kasetsart University.

Levine, Gilbert and Henry C. Hart. 1981. Mobilizing Local Resources for Irrigation. Report No. 22. Research and Training Network Program, Agricultural Development Council.

Lewis, Henry T. 1971. Ilocano Rice Farmers: A Comparative Study of Two Philippine Barrios. Honolulu: University of Hawaii Press.

Maass, Arthur and Raymond L. Anderson. 1978. . . . and the Desert Shall Rejoice: Conflict, Growth and Justice in Arid Environments. Cambridge, Mass.: The MIT Press.

Marglin, Stephen. 1966. "Objectives of Water-Resource Development: A General Statement." In: Design of Water Resource Systems. Cambridge: Harvard University Press.

McKean, R. 1974. "Property Rights Within Government, and Devices to Increase Governmental Efficiency." In: Eirik G. Furubotn and Svetozar Pejovich (eds.). The Economics of Property Rights. Cambridge, Mass.: Ballinger Publishing Co.

Minhas, B.S. et al. 1974. "Toward the Structure of a Production Function for Wheat Yields with Dated Inputs of Irrigation Water." Water Resources Research, Vol. 10 No. 3.

Mitchell, William P. 1973. "The Hydraulic Hypothesis: A Reappraisal." Current Anthropology 14.

Mitchell, William P. 1976. "Irrigation Farming in the Andes: Evolutionary Implications. In: Rhoda Halperin and James Dow (eds.). Studies in Peasant Livelihood. New York: St. Martin's Press.

Moerman, Michael. 1968. Agricultural Change and Peasant Choice in a Thai Village. Berkeley: University of California Press.

Nanda, Ved P. (ed.). 1977. Water Needs for the Future: Political, Economic, Legal, and Technological Issues in a National and International Framework. Boulder, Colorado: Westview Press.

Nash, Manning. 1965. The Golden Road to Modernity: Village Life in Contemporary Burma. New York: John Wiley & Sons, Inc.

National Planning Commission. 1972. The Fourth Five-Year Plan. Kathmandu: National Planning Commission.

National Planning Commission Secretariat. 1979. Basic Principles of the Sixth Plan (1980-1985). Kathmandu: National Planning Commission.

Netting, Robert McC. 1974. "Agrarian Ecology." Annual Review of Anthropology, Vol. 3.

Nichols, Sandra. 1982. The Fragile Mountain. (Motion Picture). Newport, R.I.: Sandra Nichols Productions.

Oad, Ramchand. 1982. Water Management and Relative Water Supply in Irrigation Systems of Indonesia. Unpublished Ph.D. dissertation. Ithaca: Cornell University.

Pachico, Douglas H. 1980. Small Farmer Decision Making: An Economic Analysis of Three Farming Systems in the Hills of Nepal. Unpublished Ph.D. dissertation. Ithaca: Cornell University.

Palerm, Angel. 1955. "The Agricultural Basis of Urban Civilization in Mesoamerica." In: Julian H. Steward(ed.). Irrigation Civilizations: A Comparative Study. Washington: Social Science Section, Department of Cultural Affairs, Pan American Union.

Parsons, Kenneth H. 1942. "John R. Commons' Point of View." The Journal of Land and Public Utility Economics, Vol. XVIII No. 3.

Pradhan, Bharat Bahadur. 1981. "The Overlooked Link in Agricultural Planning--the Farmer." Unpublished paper. Kathmandu.

Pradhan, Bharat Bahadur. 1982. "Participatory Irrigation Management." Paper prepared for the World Bank. Kathmandu: Sir M MacDonald & Partners Ltd.

Pradhan, B.K. 1976. "Irrigation Development in Nepal." Paper presented at Council for Science and Technology Seminar. Kathmandu.

Pradhan, Prachanda. 1983. "Community-managed Irrigation Systems Case Study: Chhatis Mauja Irrigation System." In: Water Management in Nepal. Proceedings of the Seminar on Water Management Issues held in Kathmandu, 31st July to 2nd August 1983. Kathmandu: Ministry of Agriculture/Agricultural Projects Services Centre/Agricultural Development Council, Inc.

Randall, Alan. 1974. "Coasean Externality Theory in a Policy Context." Natural Resources Journal 14.

Randall, Alan. 1975. "Property Rights and Social Microeconomics." Natural Resources Journal, Vol. 15 No. 4.

Regmi, Mahesh C. 1972. A Study in Nepali Economic History, 1768-1846. New Delhi: Manjusri Publishing House.

Regmi, Mahesh C. 1978. Land Tenure and Taxation in Nepal. Kathmandu: Ratna Pustak Bhandar.

Rieger et al. 1976. Nepal Report. Heidelberg: Himalayan Ecosystems Research Mission, Heidelberg University.

Runge, Carlisle Ford. 1981. "Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context." American Journal of Agricultural Economics, Vol. 63.

Runge, Carlisle Ford. 1984. "Common Property and Collective Action in Economic Development." Working Paper No. 1. St. Paul, Minn.: Center for Natural Resources Policy and Management Studies, University of Minnesota.

Runge, Carlisle Ford. 1984. "Strategic Interdependence in Models of Property Rights." Invited paper presented to the annual meeting of the American Agricultural Economics Association, August 5-8, 1984. Ithaca: Cornell University.

Schotter, Andrew. 1981. The Economic Theory of Social Institutions. Cambridge: Cambridge University Press.

Seckler, David. 1985. "The Management of Padi Irrigation Systems: A Laissez-Faire, Supply-Side Theory." in Irrigation Management Network Paper 11b. London: Agricultural Administration, Overseas Development Institute.

Seckler, David and Deep Joshi. 1981. "Sukhomajri: A Rural Development Program in India." (mimeo) New Delhi: Ford Foundation.

Siy, Robert Y. Jr. 1982. Community Resource Management: Lessons from the Zanjera. Quezon City: University of the Philippines Press.

Small, Leslie and C.L. Chen. 1984. An Approach to Estimating the Potential Benefits from Improved Irrigation Water Management for Rice. New Jersey Agricultural Experiment Station Publication. No. J-02119-2-84. New Brunswick, NJ.

Smith, Stephen C. and Emery N. Castle (eds.). 1964. Economics and Public Policy in Water Resources Development. Ames, Iowa: Iowa State University Press.

Steward, Jane C. and Robert F. Murphy (eds.). 1977. Evolution and Ecology. Urbana: University of Illinois Press.

Svendsen, Mark. 1983. Water Management Strategies and Practices at the Tertiary Level: Three Philippine Irrigation Systems. Unpublished Ph.D. dissertation. Ithaca: Cornell University.

Tan-kim-yong, Uraivan. 1983. Resource Mobilization in Traditional Irrigation Systems of Northern Thailand: A Comparison Between the

Lowland and the Upland Irrigation Communities. Unpublished Ph.D. dissertation. Ithaca: Cornell University.

Thiessen, E. 1983. AHREP Headrace Irrigation: Preliminary Feasibility Report. Kathmandu: United Mission to Nepal.

Tregarthen, Timothy D. 1977. "The Market for Property Rights in Water." In: Ved P. Nanda (ed.). Water Needs for the Future: Political, Economic, Legal, and Technological Issues in a National and International Framework. Boulder, Colorado: Westview Press.

Tregarthen, Timothy D. 1983. "Water in Colorado: Fear and Loathing of the Marketplace." In. Terry L. Anderson (ed.). Water Rights: Scarce Resource Allocation, Bureaucracy, and the Environment. Cambridge, Mass.: Ballinger Publishing Co.

Trelease, Frank J. 1965. "Policies for Water Law: Property Rights, Economic Forces, and Public Regulations." Natural Resources Journal, Vol. 5 No. 1.

Upadhyay, S.K. and G.P. Koirala. 1981. "Production Incentives for Hill Agricultural Development." In: Nepal's Experience in Hill Agricultural Development. Kathmandu: Ministry of Food and Agriculture.

Uphoff, Norman. 1984. "Analyzing Options for Local Institutional Development." Special Series on Local Institutional Development, No. 1. Ithaca: Rural Development Committee, Cornell University.

Uphoff, Norman. 1985. "Developing Water Management Institutions in Sri Lanka: Understanding Collective Action and Managing Common Resources." Paper for ASPA Panel on "Developing Institutions for National Development: A Comparative Analysis of Analytic Frameworks and Contemporary Practice in Natural Resource Management Institutions." Bloomington.

Uphoff, Norman, Ruth Meinzen-Dick, and Nancy St. Julien. 1985. "Getting the Process Right: Farmer Organization and Participation in Irrigation Water Management." A State-of-the-Art Paper prepared at Cornell University for the Water Management Synthesis II Project, Consortium for International Development. Ithaca: Cornell University.

Uphoff, Norman, M. L. Wickramasinghe and C. M. Wijayaratna. 1981. "'Optimum' Participation in Water Management: Issues and Evidence from Sri Lanka." Paper for Rural Development Committee, Cornell University, Ithaca, and Agrarian Research and Training Institute, Colombo.

Valera, A. and T. Wickham. 1974. "Land Preparation in Lowland Rice: Its Speed in Relation to Rate of Water Supply." Paper presented at the

Philippine Society of Agricultural Engineers Annual Convention, April 18-19, 1974. Manila.

Water and Energy Commission. 1981. Irrigation Sector Review. Kathmandu: Ministry of Water Resources.

Wickham, T.H. 1971. Water Management in the Humid Tropics: A Farm Level Analysis. Unpublished Ph.D. dissertation. Ithaca: Cornell University.

Wittfogel, Karl A. 1955. Oriental Despotism: A Comparative Study of Total Power. New Haven: Yale University Press.

Woodbury, Richard B. (ed.) 1962. Civilization in Desert Lands. University of Utah Anthropological Papers, No. 62. Salt Lake City: University of Utah.

Wong, Benedict D. C. and J. Wayland Eheart. 1983. "Market Simulations for Irrigation Water Rights: A Hypothetical Case Study." Water Resources Research, Vol. 19 No. 5.